JOURNAL OF

METALS

DECEMBER 1958

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The C & D Hot Top we recommend for you will be prescribed only after a close-up study of your individual situation —will be customized to fit *your* job. C & D service will then follow through in your plant to assure you of the maximum in sound killed steel—of ingots uniform in quality—of deliveries as required. In short—*dependability*—every time—since 1929.

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JOURNAL OF

METALS

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December, 1958

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PERSONNEL

► These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Civil, Electrical, Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for non-members, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., *New York 18*; 57 Post St., *San Francisco*; 84 E. Randolph St., *Chicago 1*.

— MEN AVAILABLE —

Sales or Plant Manager, B.S. Met. Engr. and Bachelor Foreign Trade, age 35. Administration—Sales. Nine years sales and supervisory experience in metals, metal working, process equipment, industrial gas. Four years in Latin America. Fluent Spanish. Location, domestic or foreign. M-201.

Metallurgical Technician or Engineering Aide, age 24, working towards bachelor of metallurgical engineering degree at night; has completed 95 credits and taken courses in physical, mechanical, electrometallurgy, ferrous and non-ferrous metallurgy. Desires position involving physical or mechanical metallurgy. M-202.

— POSITIONS OPEN —

Metallurgy Engineers. a) One for a development and research department, M.S. in Metallurgy or Metallurgical engineering preferred, with a minimum of three years experience in problems pertaining to foundry, machine shop and welding. Salary, $7800 a year. b) One for alloy division M.S. in Metallurgy or Metallurgical engineering preferred, with a minimum of three years experience on research projects pertaining to elevated temperature, heat, corrosion and special analysis on steel castings. Must be able to follow through and direct research projects. Salary, $6600 a year. Location, western Pennsylvania. W6660.

Metallurgists. a) Research Metallurgists with good background in inorganic chemistry, one to ten years experience. Will lead to assist in projects in hydrometallurgy, pyrometallurgy, and mineral beneficiation. Salary open. b) Physical Metallurgist with five to ten years experience. Background in powder metallurgy and related fields of particular interest. Will head up projects. Salary open. Location, western Canada. F6652.

Metallurgical Engineer with one to three years experience in copper and brass fabrication plants. Salary open. Location, central New Jersey. W6650.

Physical Metallurgist for a fully integrated, modern aluminum plant, with three to five years experience in aluminum (or non-ferrous metal) especially in casting and rolling desirable; if recent graduate, Master's degree minimum requirement. Apply by letter, giving complete information. Location, Mid-South. W6588.

Instructor in nuclear metallurgy as part of M.S. program in nuclear engineering; Ph.D. degree preferred. Background in one or several of the following fields also desirable: X-ray, Thermodynamics, Mechanical Metallurgy or Solid State. Research support. Salary and rank open. Location, Midwest. W6529.

Engineers. a) Production Specifications Engineer, degree in metallurgical engineering or mechanical engineering, with eight to ten years experience in solving production problems in foundry, rolling, swaging, forging and sheet metal fabrication. Must be strong in the preparation of manufacturing specifications and the determination of types of inspection and procedures to insure a high quality product. Salary open. b) Quality Control Engineer, graduate metallurgical or mechanical engineer, with courses in industrial management and manufacturing processes; special training in statistics, quality control and analysis of data. Three to five years in shop trouble shooting, methods work, processes engineering and quality control, to make economic studies of losses, setup to collect inspection data for identifying sources of defects, etc. Salary open. Location, New York Metropolitan area. W6508.

Department Head for a school of engineering; Ph.D. required, to head up metallurgical work. Must be a promising young man who recently secured Doctor's degree in metallurgical engineering. Salary open. Location, South. W6455.

Metallurgist, B.S. or M.S., with at least three years in research. Will prepare, under supervision, research programs; with aid of technicians prepare tests and write formal report at end of research. Field of research includes supervision of creep

(Continued on page 756)

Welding Metallurgist

Physical metallurgist, preferably with advanced degree and with considerable experience in welding metallurgy, is needed to head laboratory study of fabricating problems encountered in petroleum refining and petrochemical plants. Work involves evaluation of equipment and the development of optimum procedures for shop use. Some trouble-shooting on plant problems. Requires an acknowledged expert who can conceive and carry out independently his own program. Well equipped, modern laboratories in Whiting, Indiana (near Chicago). Age to 45. Salary in keeping with training and experience. Reply in confidence to:

T. A. Abbott, Manager
Engineering Administration
Standard Oil Company (Indiana)
2400 New York Ave. Whiting, Indiana

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New Nuclear Core Operation at The Knolls Atomic Power Laboratory opens outstanding opportunities for

METALLURGISTS

If your experience includes 3 to 5 years in process metallurgy, you are invited to apply for openings in process development, process evaluation, non-destructive test and surface chemistry. Minimum, BS in Metallurgy is required.

You'll find excellent housing readily available; liberal relocation allowances apply. U.S. citizenship required.

Salary commensurate with background.

Send complete resume and salary requirement in confidence to:

Mr. A. J. Scipione,

Dept. 37-MX

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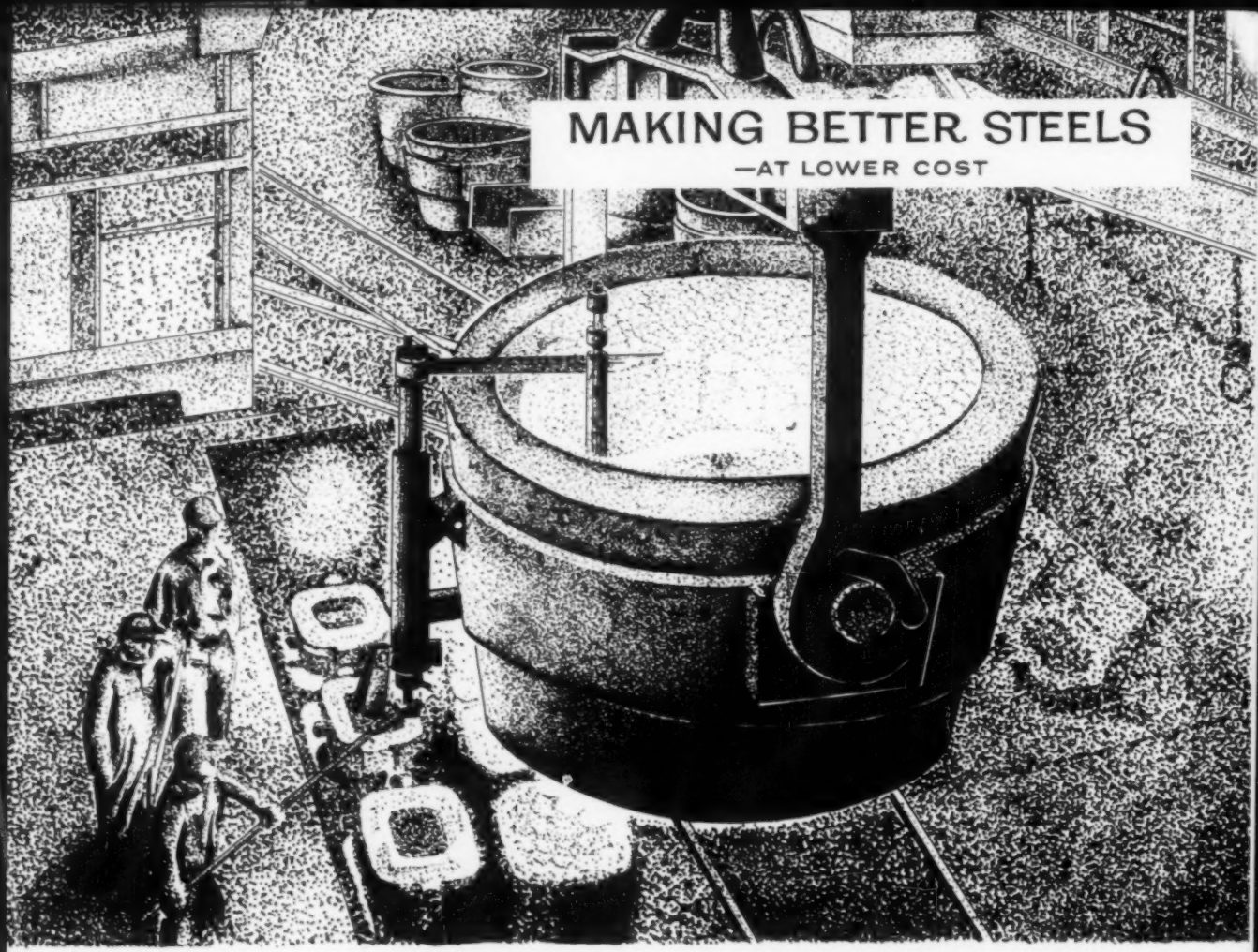

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. . . top quality steel from ladle to ingot climaxes another job well done by melters who know every trick of their trade.

Experienced melters have also discovered that **GLC GRAPHITE ELECTRODES** with **"weld-strength" Unitrode**® nipples help make better steels at lower cost.

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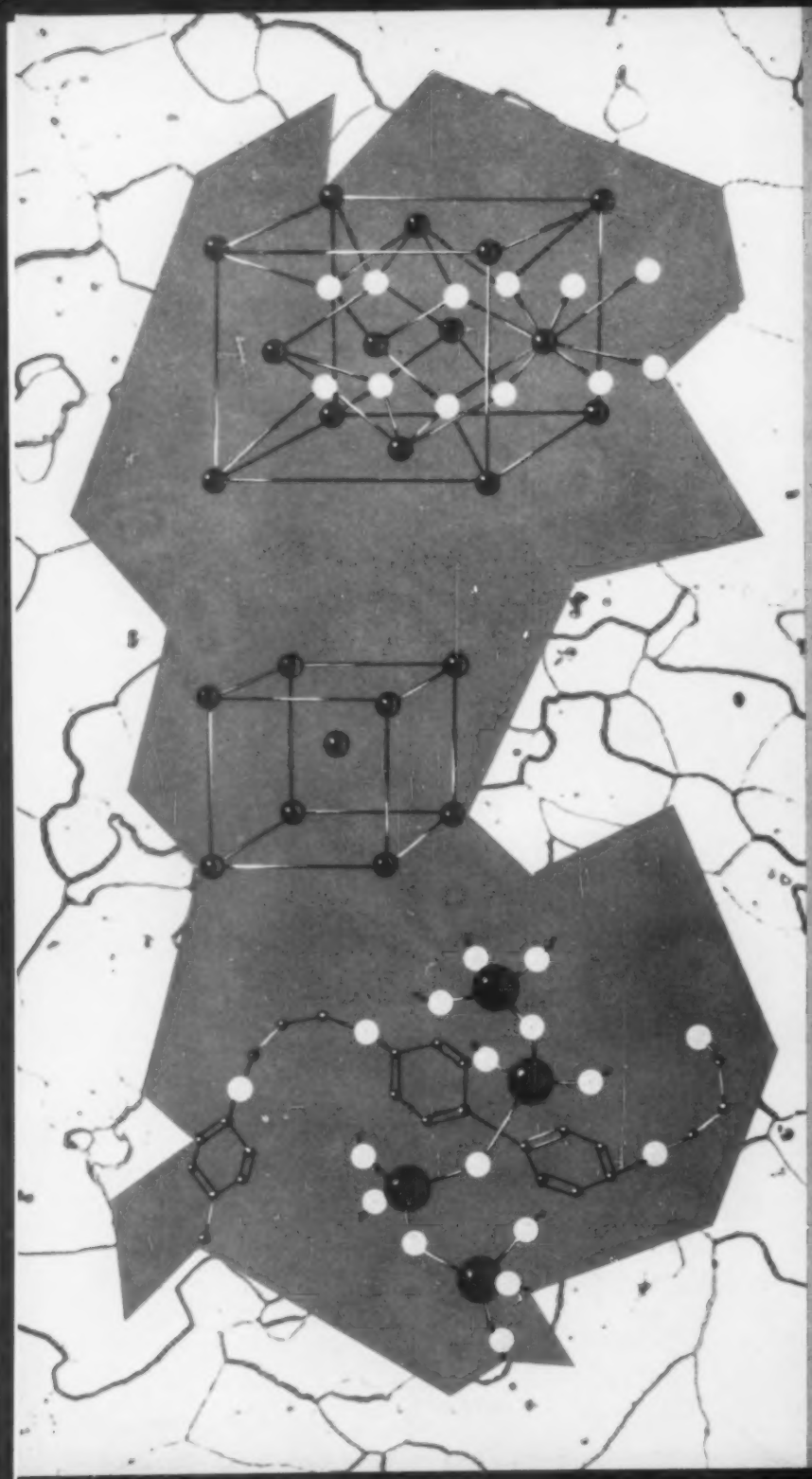

NEW APPROACH TO "OLD" MATERIALS

By today's standards, the "old" refractory metals are outdated. The ultimate in high-temperature studies of 10 years ago is several generations behind in terms of modern aircraft and missile development.

Today's material requirements surpass anything envisioned 10 short years ago. Molybdenum and beryllium, for example, are still exciting metals with much promise for space vehicles and ultra-high-speed aircraft. It now appears, however, that the full promise of such metals may be fulfilled when they are used, not alone, nor as alloys, but when combined with other materials to form totally new types of structural materials.

Such a "marriage" of metals, ceramics and plastics is a promising approach to high-temperature problems that is being vigorously pursued at Avco. It opens new potential applications for many exotic combinations.

These bold steps forward are possible at Avco, where materials research includes concurrent basic studies and applied research, plus developmental programs that extend through the solution of processing and testing problems.

The search for new knowledge goes forward simultaneously with the creation of advanced technology at Avco's Research and Advanced Development Division. The creative man, whether he is interested in basic studies or practical problems, finds his effort enhanced by the stimulus of interdisciplinary contact and feedback from other related fields.

Research and Advanced Development is more than a descriptive title at Avco. It is a concept that promotes creativity.

Avco

Research and Advanced Development division

For information on unusual career opportunities for exceptionally qualified scientists and engineers, write to: Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Div.; 201 Lowell Street, Wilmington, Mass.

ROOF LIFE DATA FOR 1000-LB. DIRECT ARC ELECTRIC FURNACE
plastic firebrick roofs 33 heat average
mullite plastic 116 heat average
TAYCOR Ramming Mix first roof—241 heats second roof—254 heats

Roof of TAYCOR Ramming Mix for 1000-lb. direct arc furnace after 254th heat.

Extra HEATS

gained by TAYCOR roofs for direct arc furnace

The Fahralloy Company, Harvey, Illinois, operates a 1000-lb. basic direct arc furnace, melting 30-35 heats of heat and corrosion resistance alloys per week. Usual charge is 1500 lbs.

After changing from acid to basic furnace practice, tests were run with the following results: Silica roofs averaged 13 heats. Super-duty plastic firebrick roofs averaged 33 heats. Rammed roofs of competitive mullite plastic averaged 116 heats.

The first TAYCOR rammed roof set a record of 241 heats. The next TAYCOR roof jumped the record to 254 heats, some of them up to 3600-lb. triple sized ones.

Among the TAYCOR advantages reported by Fahralloy are:

Longer roof life
No dripping
Longer sidewall life
Less slag

Try TAYCOR Ramming Mix for your next direct arc roof. Let the Taylor field engineer in your area give you full details.

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The CHAS. TAYLOR SONS Co.
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Positions Open

(Continued from page 752)

and stress rupture testing; determination of best heat treatment and welding practice for suitable alloys; corrosion test various alloys; investigation of service failure, prevention recommendations, and research on hard facing materials. Salary open depending upon experience. Employer may negotiate placement fee. Location, southern Chicago area. C7062A.

Senior Metallurgist, B.S. and M.S. in mineral dressing or metallurgy from recognized mining school; minimum of ten years experience combined operations and research in non-ferrous minerals beneficiation. To have line control of principal ore dressing laboratory and pilot plant and functional control over metallurgy at five operating concentrators. Conduct special plant studies; make economic evaluation and flowsheet and basis of designs for new plants and additions. Married or single. Salary, $7800-9600 a year. Employer pays placement fee. Location, Peru. S3901R.

Metallurgical Engineer-Uranium Mill, B.S. or M.S., with experience in extractive and hydrometallurgy;

(Continued on page 763)

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PHYSICAL METALLURGISTS, for research and development in high temperature materials. Advanced degree and minimum of 3 years experience, including X-ray diffraction, metallographic inspection and experimentation with ultra-high temperature physical properties. Familiarity with powder metallurgical techniques preferred.

Qualified applicants are invited to send resumes and inquiries to Mr. L. R. Stapel.

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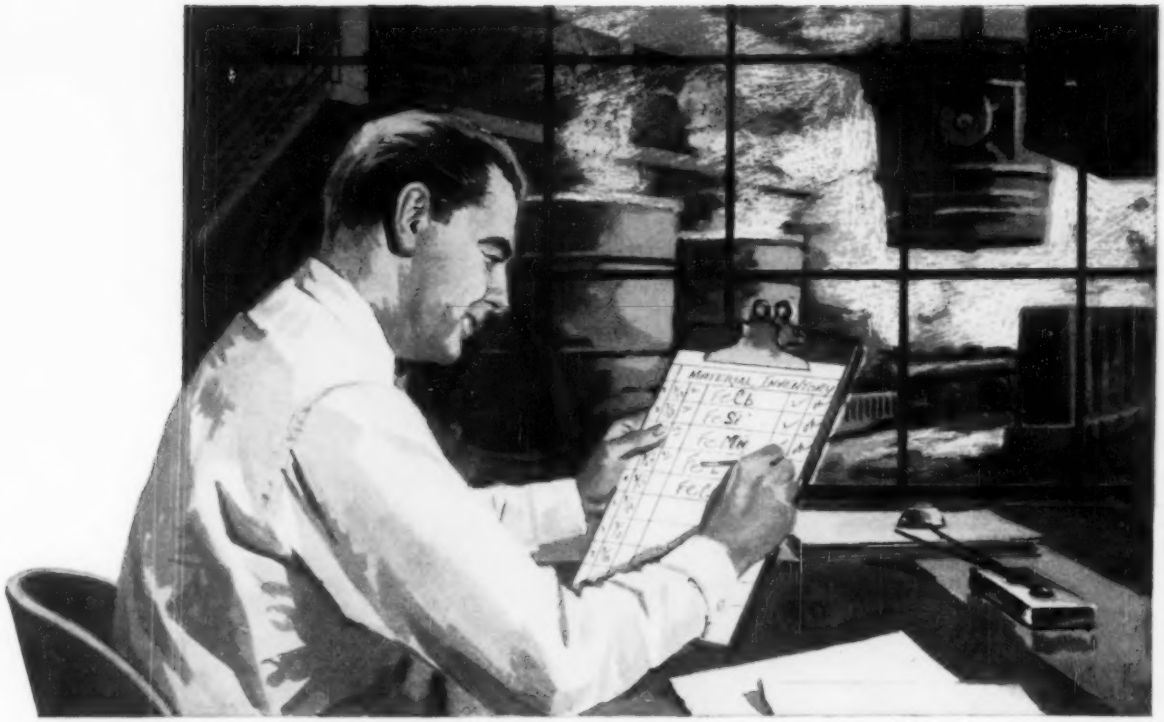

Unlimited

Columbium for industry

With the world's largest raw material reserve of columbium, MCA can now assure steelmakers that columbium is readily available in quantity and will continue to be in plentiful supply for future needs.

New uses for columbium have recently been announced by steelmakers. Small amounts give greatly increased properties for strip, sheet and plate steel. In Type 347 stainless, for example, long recognized for reliability in corrosion resistance, manufacturers no longer are faced with imposed restrictions requiring the use of substitute materials. Welding rods destined for severe service offer another advantageous use for columbium.

MCA has developed a new low melting ferro columbium for open hearth use. We are prepared to give metallurgical and technical advice on its application for mold and ladle additions.

MOLYBDENUM

Grant Building CORPORATION OF AMERICA **Pittsburgh 19, Pa.**

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Plants: Washington, Pa., York, Pa.

MCA

Formability—In days of old, when knights were bold, they also were smart. When their very lives depended on a tool or a weapon, they made sure it was made from steel. It could be a great claymore, hefty enough to behead a horse; a bright suit of armor that would turn the Saracen's arrow; or an ornamental castle gate, strongly made to frustrate the assassin.

They wanted steel because it was strong. They could *use* it because it was formable. Truly, there is no economical metal in all the world that can approach steel's combination of strength and formability.

With the near-magic of heat treating, you can soften steel and form it, then harden it to make it strong, then temper it to make it tough. Or form it cold. Use bending, flanging, deep drawing, spinning, cold heading, die drawing, rolling, wiper forming, draw rolling, stretch forming or bumping. In fact, it's hard to imagine any forming operation that cannot be performed on steel.

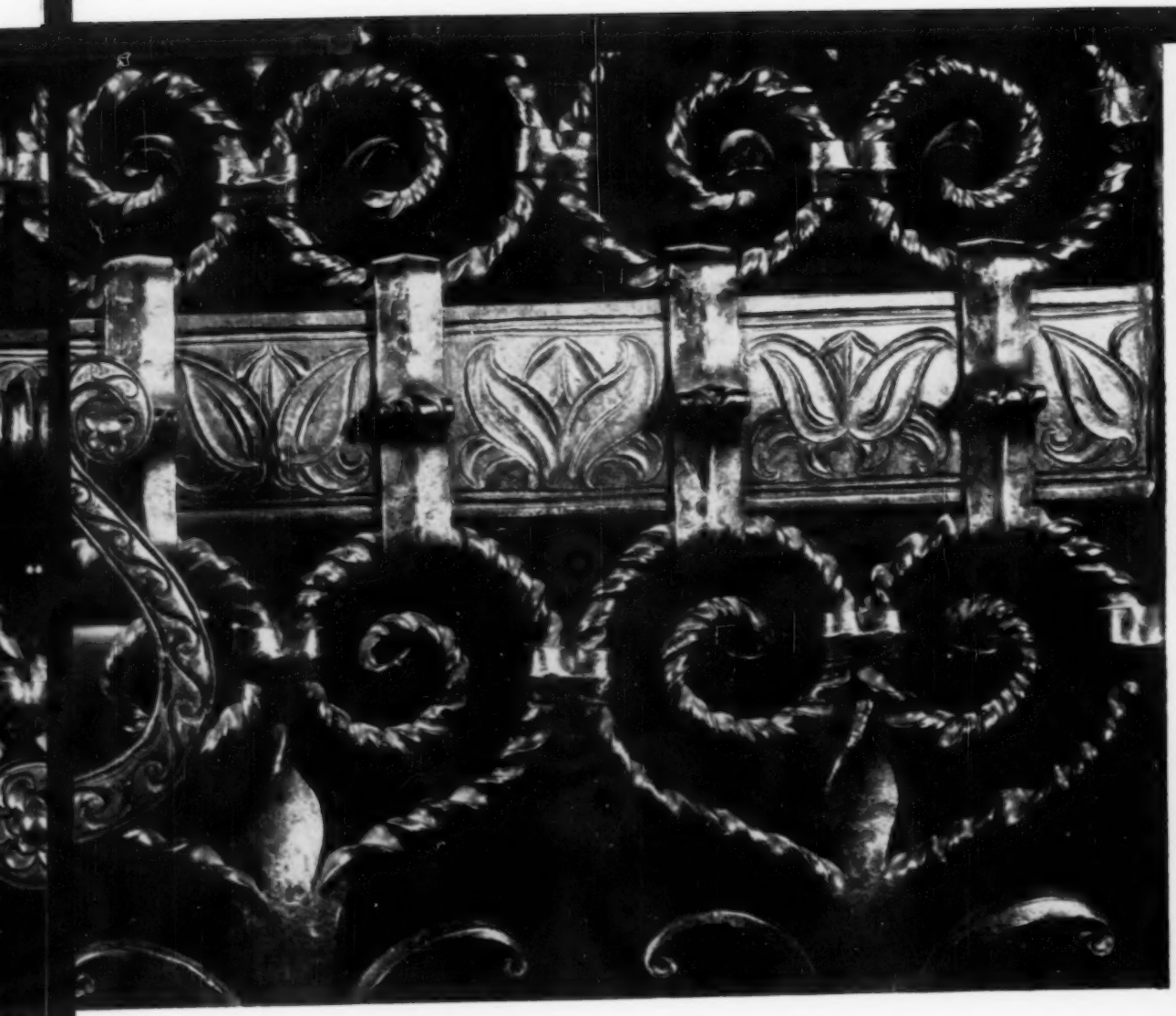
Fortunately, there are hundreds of different kinds of steel; and they all act differently in the fabricating shop. Everything you do to steel alters its *forming* properties, and every forming operation alters its physical properties.

The aim of the product designer is to find a steel that can be properly formed, that has the right strength, toughness, corrosion resistance, weldability or other characteristics required . . . at the most favorable cost. If you have a design problem and the comptroller is looking over your shoulder, take hope from this idea: there is one "best" steel for any design application. You can be sure of finding it among the great family of USS Design Steels: Carbon, High Strength, Alloy and Stainless Steels.

If you need help in making your selection, ask a company that has produced well over a billion tons of steel, and has spent hundreds of millions of dollars to learn more about this most versatile of man's metals. Of course that means United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

United States Steel Corporation • American Steel & Wire • Columbia-Geneva Steel • National Tube
Tennessee Coal & Iron • United States Steel Supply • United States Steel Export Company

USS United States Steel



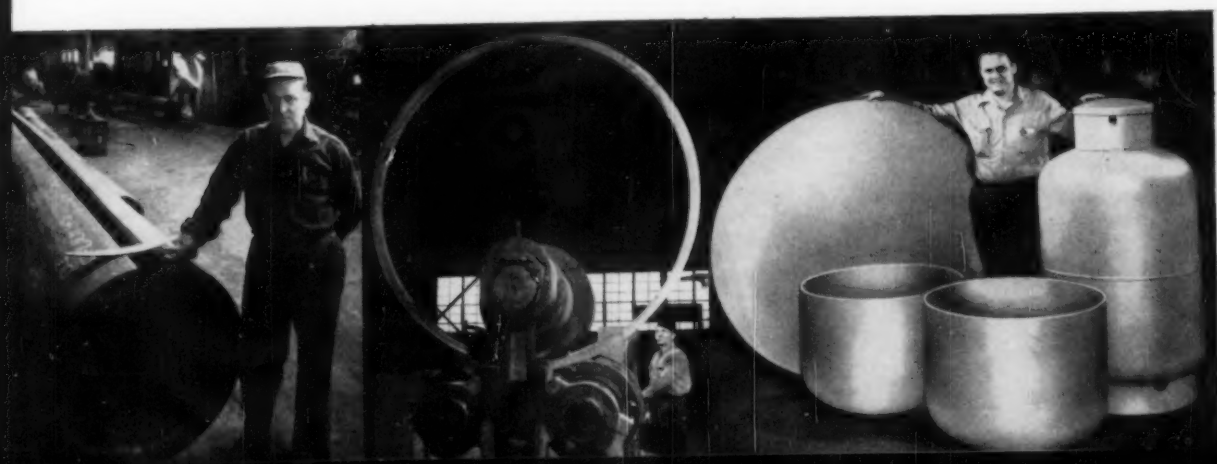
STEELS FOR DESIGN

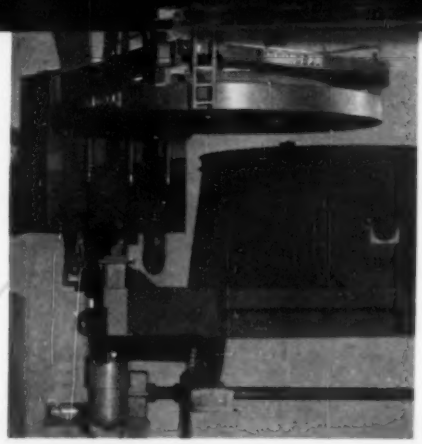
Lower Left—Problem: Build a power shovel dipper stick with greater strength and shock resistance. Solution: Bucyrus-Erie Company designed a tubular stick made from USS "T-1" Constructional Alloy Steel. Payoff: The "T-1" Steel plates were easily cold-formed into a tube and butt welded. The tubular design and stronger steel assured great strength and shock resistance, and easy fabrication.

Lower Middle—Problem: Produce strong, heat resistant, corrosion resistant jet engine rings—*economically*. Solution: Alloy Manufacturing Company carefully selected a grade of USS Stainless Steel. Payoff: The rings resist heat and corrosion and they are economically roll-formed because the Stainless Steel is formed on "carbon steel rated" equipment.

Lower Right—Problem: Design a pressure tank that is just as strong but lighter than conventional carbon steel tanks. Solution: Manufacturer selected USS MAN-TEN High Strength Steel. Payoff: MAN-TEN's greater strength (50% higher yield point than carbon steel) permitted design of a thinner-walled tank that is 24% lighter. And because MAN-TEN is highly formable, the tank is economically produced by cold press forming of circular blanks into seamless shells, 29" in diameter and 24" deep.

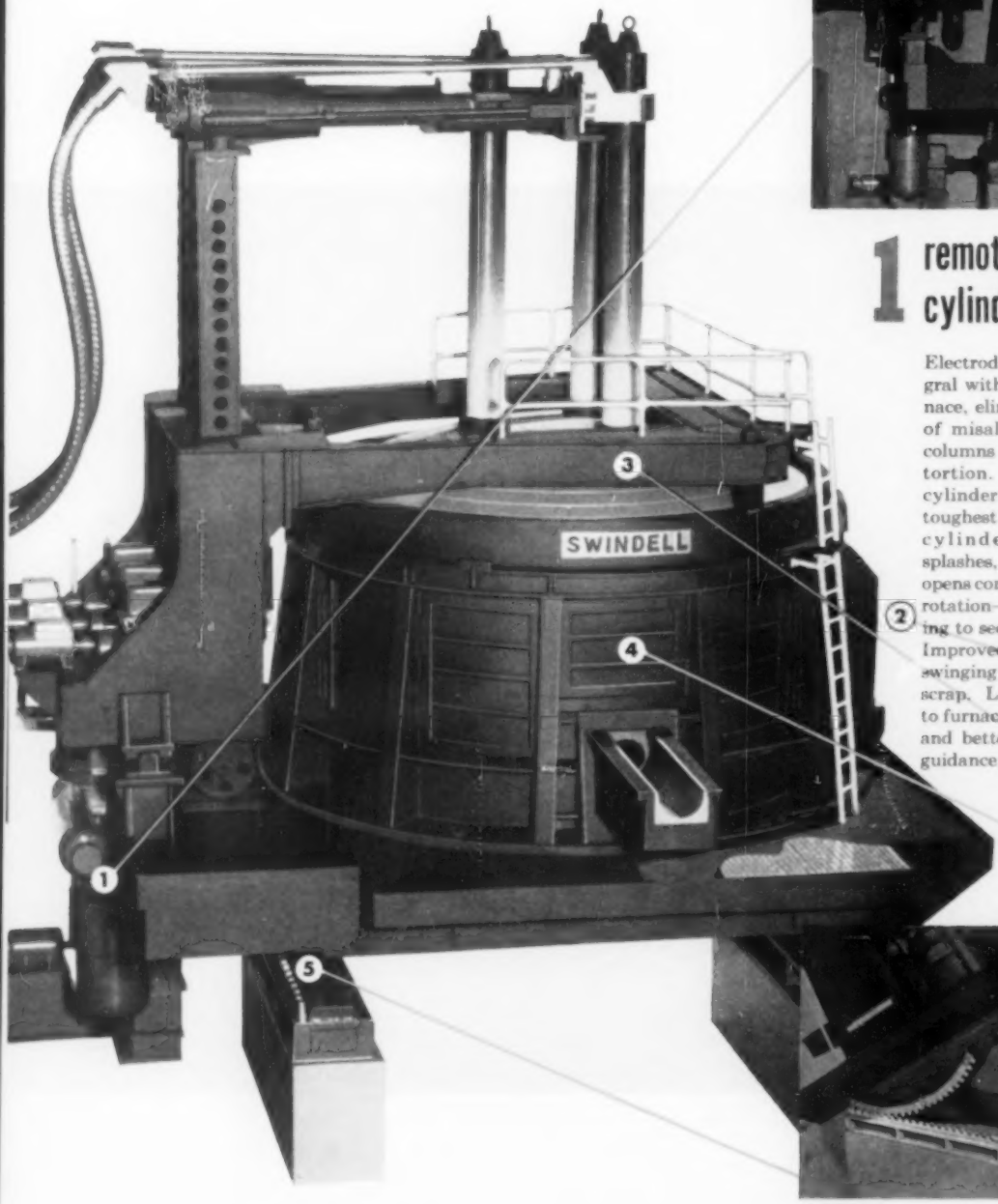
USS, "T-1" and Man-Ten are registered trademarks

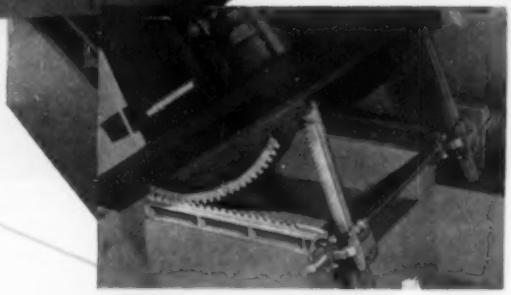




1 remote roof cylinder mounting

Electrode superstructure integral with tilting portion of furnace, eliminates any possibility of misalignment of electrode columns from shell or roof distortion. Rugged time proven cylinder for plowing through toughest scrap. No damage to cylinder from hot metal splashes, scrap or runouts. Roof opens completely with minimum rotation—no cross-over and fouling to secondary flexible cables. Improved lift stroke facilitates swinging roof over pyramided scrap. Low center of gravity to furnace. Improved wheelbase and better protection for mast guidance.





5 mechanical tilting

Eliminates the foundation expense, fire hazard, mess, and maintenance of hydraulic cylinder tilting. Provides variable speeds of tilt to 1° per second. Safe, dependable, time-proved—engineered to be out of danger of damage by hot slag, runouts, etc. Minimum maintenance, maximum accessibility. Fail-safe design permits emergency manual tilting from safety of operating floor.

ENGINEERING SERVICE

Swindell-Dressler Corporation provides a complete engineering service for the steel industry in the design and construction of new plants, and modernization of existing facilities. Consultations arranged gladly on request.

The features that make perfection
IN ELECTRIC ARC MELTING PERFORMANCE

2 flush door mechanism

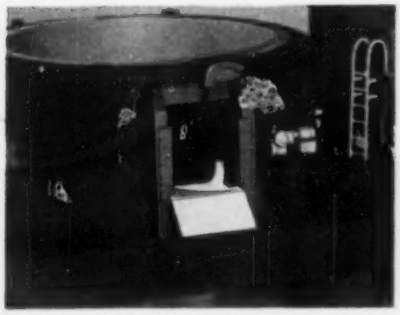
Permits rapid charging through fast, accurate placement and removal of charging bucket without maneuvering. Prevents damage by charging bucket or magnet to door guides, hoist mechanism and drives. Door cheeks and guides are designed to permit greater access to all of hearth area for maintenance.

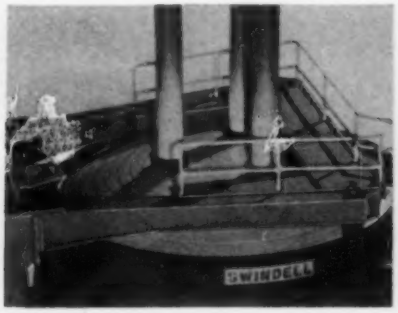
3 3 point roof suspension

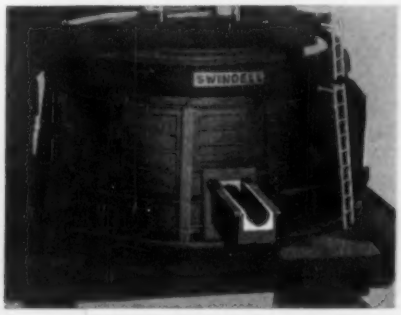
Distributes roof load equally to water-cooled roof suspension beams—prevents roof ring distortion in lifting—permits roof to "float," safeguarding electrode alignment if shell sidewalls expand, yet is rigid in horizontal plane to guard against damage if swinging roof collides with pyramiding scrap. Oversize diameter roof ring of exclusive I-beam design.

4 expendable shell panel construction

Localizes any shell damage—safeguards balance of furnace and its alignment. Panels can be easily replaced without disturbing refractory sidewalls. Panels can "breathe" for expansion and contraction. Water-cooled annular ring ties heavy buckstays at parting line.







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DESIGNERS AND BUILDERS OF MODERN INDUSTRIAL FURNACES

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Keep Your Furnaces Operating!

FOR MAXIMUM AVAILABILITY BALANCE YOUR REFRACTORY LIFE WITH CORHART 104!

Now that steel production is getting back to normal, you can meet the new production challenge *without adding new furnaces.*

21 major steel producers today are getting increased availability by *balancing** their electric furnaces with Corhart 104, a vastly superior fused basic refractory. Result: Longer furnace life, less downtime, lower costs.

Corhart 104 has unique interlocking structure, non-connecting porosity, high density and greater mechanical strength at operating temperatures.

It is more impermeable to gases and slags, and has greater resistance to arc impingement, corrosion and slag erosion.

An experienced Corhart refractory engineer will be glad to study your furnaces and make recommendations. Address: Corhart Refractories Company, Incorporated, 942 Commonwealth Bldg., Louisville, Kentucky, U.S.A., Telephone—JUniper 5-4201.

**Proper selection of the best refractory materials and proper engineering of wall thicknesses.*

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CORHART 104 ELECTROCAST REFRACTORY

Subsidiary of Corning Glass Works

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Positions Open

(Continued from page 763)

knowledge of ion-exchange principles desirable but not essential. Will be metallurgist at uranium mill operated by well established, medium-sized company. Salary, $7200-9000, depending on qualifications. Liberal housing benefits. Location, Southwest. S3929.

2 METALLOGRAPHERS

Positions include: — analytical, testing, and experimental work on reactive metals, such as zirconium, uranium and thorium; and base metals, such as aluminum and stainless steel. Facilities are new, well laid out, and equipped with the most modern polishing, microscope and dark room equipment.

Must be team men — work well with other people. These permanent positions offer liberal salary, profit-sharing and pension plans. Plenty of room for advancement.

Modern plant located in suburban Massachusetts with easy access to Cape Cod and Narragansett Bay.

Send resume to Mr. Tom Fowler

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History of the British Iron and Steel Industry, by H. R. Schubert. The Macmillan Co., 60 Fifth Ave., New York 11, N. Y., 445 pp., $12.00, 1958.—This book is the first comprehensive history of British iron and steel making from its earliest appearance in pre-historic times to the introduction of steam power. The period concerned is essentially marked by the use of charcoal as fuel. The evolution of furnaces, mechanical devices and methods is based upon much new documentary evidence. The book deals lucidly with many fascinating technical and archaeological problems and is copiously illustrated to make the subject interesting not only to the iron master and engineer, but also to the historian and archaeologist. •

The Metallurgy of Vanadium, by William Rostoker, *John Wiley & Sons Inc.*, 185 pp., $8.50, 1958.—This book offers a full discussion of vanadium technology. It provides a comprehensive treatment of the extraction, properties, and processing of the metal. By so doing, it serves as a ready reference for those who seek to use new materials for special applications. •

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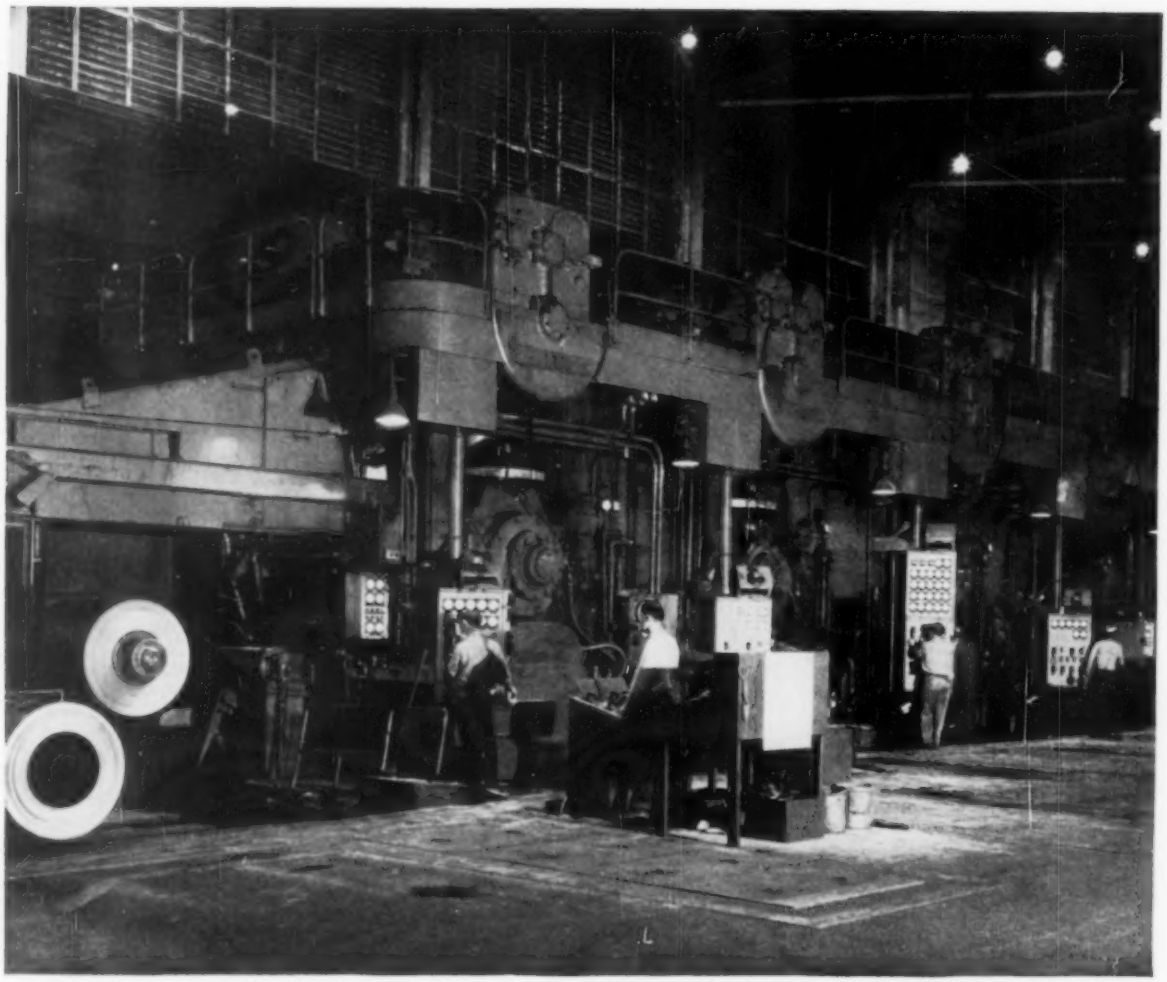

Weirton equips cold strip mill with double-poured Ni-hard working rolls

Ni-Hard nickel-chromium cast iron provides hardness of 80 to 82 Shore . . . provides long life, consistently good finish

Weirton Steel Company, a division of National Steel Corporation, is using double-poured Ni-Hard* nickel-chromium alloy iron working rolls on all five stands of its cold strip mill. These Ni-Hard rolls are 23-inches in diameter with a 52-inch face. Six stands in Weirton's hot strip mill are also equipped with Ni-Hard rolls.

Why Ni-Hard working rolls? Ni-Hard cast iron possesses a matrix structure in the mold cooled condition that is akin to that of heat treated steel. In addition, it contains a multitude of refined carbides which make an important contribution to its abrasion resistance. The resulting structure has great hardness, strength, and resistance to impact.

For your applications. Ni-Hard alloy possesses the fluidity and freezing range of the cast irons and can be readily cast in all forms and shapes common to the iron and steel foundry. If you'd like specific information concerning its application to your abrasion problem, write Inco. For details on double-poured Ni-Hard rolls, write the fabricator, United Engineering Company.

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NI-HARD

NICKEL MAKES CASTINGS PERFORM BETTER LONGER

High-quality strip from powder

Savings up to 80 pct are now possible, says E. W. Bliss Co., by producing high-quality, hot-rolled strip from powder rather than using conventional equipment and rolling methods. Bliss, in conjunction with Chemetals Corp., announced these facts: Copper strip produced from powder has higher mechanical properties than electrolytic-grade copper strip produced by conventional methods, and oxygen content is substantially lower in strip produced from powder than in electrolytic-grade strip. Process begins with chemical production of metal powder, which is fed through a hopper and mill for green compacting. Sintering precedes furnace operation. Hot-rolling and further reductions follow to produce metal completely consolidated to 100 pct density.

Dislocations eliminated from Si crystals

General Electric's Dr. William C. Dash is the discoverer of a new crystal-growing technique which eliminates dislocations from crystals of silicon larger than a man's finger. GE claims this may open the door to dislocation-free, perhaps superstrong crystals of a variety of materials in large sizes. Specially tapered *seeds* made of high-perfection material reduce the thermal shock experienced by the seed when it first touches the hot molten silicon from which the crystal is grown. The crystal must be pulled in the proper crystallographic direction so that dislocations are literally left behind as the crystal grows. Dash's largest dislocation-free crystal, which weighs about 2 oz, is similar in purity to silicon used for manufacturing transistors and other semiconductor devices.

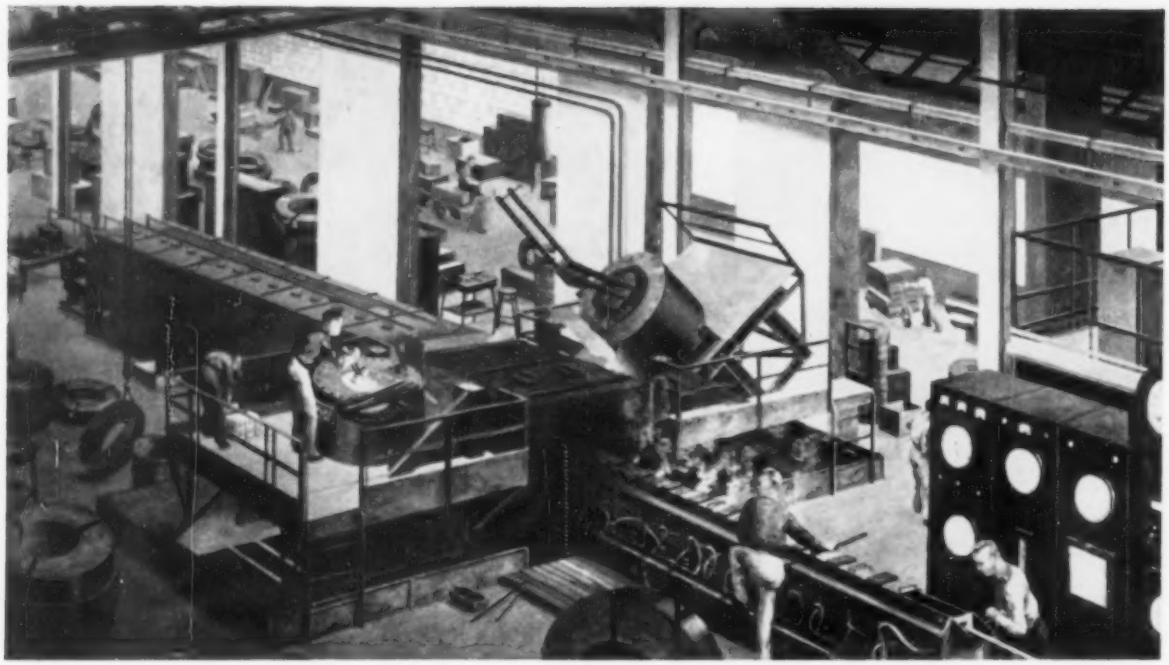
Research laboratory opened

Sylvania Electric Products, Inc. has opened a new company laboratory in Towanda, Pa., to be used for research engineering and product development in many areas of metallurgy and chemistry, and in such fields as phosphorus, semiconductor materials, spectrography, and X-ray diffraction. The new research center houses engineering offices, laboratory, and pilot plant facilities for more than 100 scientists, engineers, and technicians.

Alumina produced from nepheline in the USSR

N. Poulutoff, writing in the German journal, *Aluminium*, describes the Soviet process of producing alumina from nepheline: To extract the alumina, which is strongly attached to the constituent silicic acid and alkalis, limestone is best for the purpose. Crushed limestone and nepheline are ground in water, fed into a rotary kiln, heated at 650° to 1000° C. The result is an agglomerate consisting mainly of di-calcium silicate and sodium and potassium aluminates. The sodium and potassium aluminates go into a soda solution; the di-calcium silicate remains as a stable residue in the pulp. Washed di-calcium silicate is carried off for further treatment. About 1 ton of alumina is obtained from 4 tons of nepheline, plus about 1 ton of soda and potash, and 7 to 9 tons of cement.

REPORTER



60 CYCLE INDUCTION MELTING OF HIGH LEADED BRONZES

15 years ago, THE CLEVELAND GRAPHITE BRONZE COMPANY, division of CLEVITE CORPORATION, pioneered 60 CYCLE INDUCTION MELTING of bronzes with up to 35% lead. Special furnaces developed by AJAX for this difficult job are an important element in their unique continuous production line for steel-backed bronze bearing strip. 60 CYCLE INDUCTION MELTING furnaces resulted in substantial improvements and cost savings over gas-fired units used earlier for that purpose. Today, CLEVITE operates six continuous lines in this country and abroad with AJAX 60 CYCLE INDUCTION MELTING furnaces, producing enough strip to make 130 million bearings and bushings per year.

The heavy duty 60 cycle inductor developed by AJAX and pioneered by CLEVITE will attain a lining life of one year with bronzes of substantial lead content. Electromagnetic stirring assures uniform alloy and close temperature control. Compared to externally fired equipment, metal loss savings run into many thousands of dollars per year. Recently, several large producers of leaded bronze castings converted their foundries entirely to 60 CYCLE INDUCTION MELTING.

While this is one of the most difficult metals to handle, the advantages of 60 CYCLE INDUCTION MELTING stand out today wherever copper alloys are melted. As specialists in 60 CYCLE INDUCTION MELTING, we have developed furnace types to best fill each application.

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EDITORIAL

Our Changing Journal

One year ago we embarked on *A New Program For Publications of The Metallurgical Society* wherein a separate publication, TRANSACTIONS OF THE METALLURGICAL SOCIETY of AIME, was established and the editorial policy of the JOURNAL OF METALS was to undergo broad changes. The success of the new TRANSACTIONS will, no doubt, be discussed in this column at a later date, but we feel that now is the time to look around and see just how much the JOURNAL OF METALS has changed, where it is now, and where it ought to be heading. And thus we reach for our 1957 issues and somewhat nostalgically take stock.

As a part of the New Program for Publications, the JOURNAL OF METALS' Advisory Committee was established as a subcommittee of the Publications Committee. With trembling and fear we approached its first meeting, but we have always found the sometimes critical suggestions of this Committee sound and helpful. It has provided us with a means of finding out what you wanted to see within these covers each month. General and specific guidance has been given by the Committee, and, as a consequence, we feel that we have moved down the road toward building a more interesting, a more readable, and a more informative magazine. Through the help of the Advisory Committee we have now been able to reach out and ask many authorities of metallurgy and allied fields to write specific articles; these you will see in increasing numbers.

On our own part, we have tried to improve the general appearance of the magazine inside and out. But due to the limited size of our staff—at times only three persons—this process is of necessity a slow one.

As we stand at this one-year mark and look ahead, we say that it is our very firm intention to go much further in making the JOURNAL OF METALS the kind of magazine that you will want to put into your coat pocket and carry home from the plant or laboratory.

But . . . we want to hear from you. Sometimes we get complexes about our mail. More complaints mean that our covers are being opened. And compliments . . . well, we're human! But suggestions are what we really want. We need your help in assessing our efforts. Do you feel that we are giving you a better magazine? What could we do to improve it? Please tell us. With your help, it is our expectation to open a "Letters to the Editor" column shortly.

And now to all ye olde merry metallurgists . . . all of us wish all of you . . .

The very best of this very best Season . . .

Merry Christmas.

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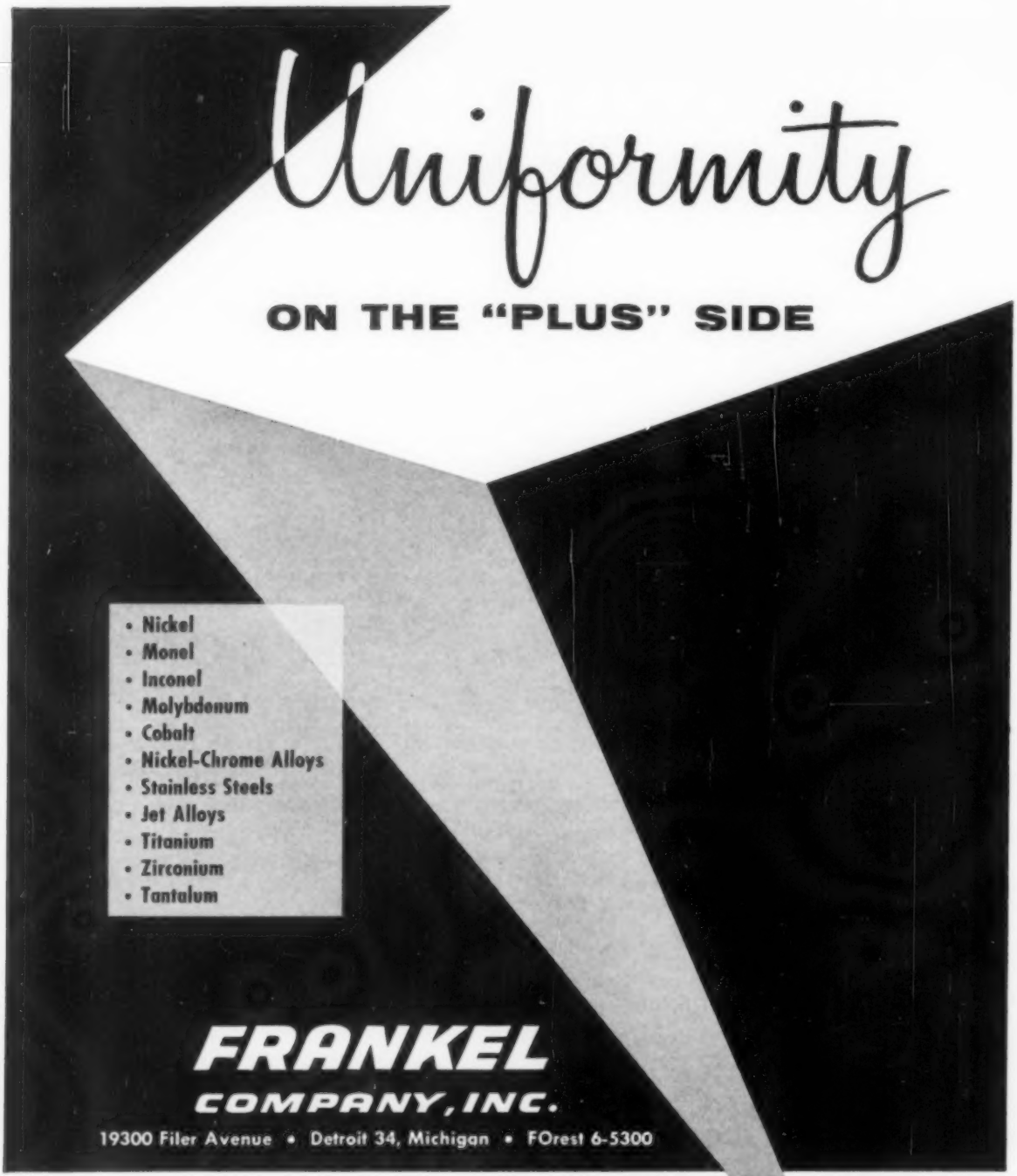

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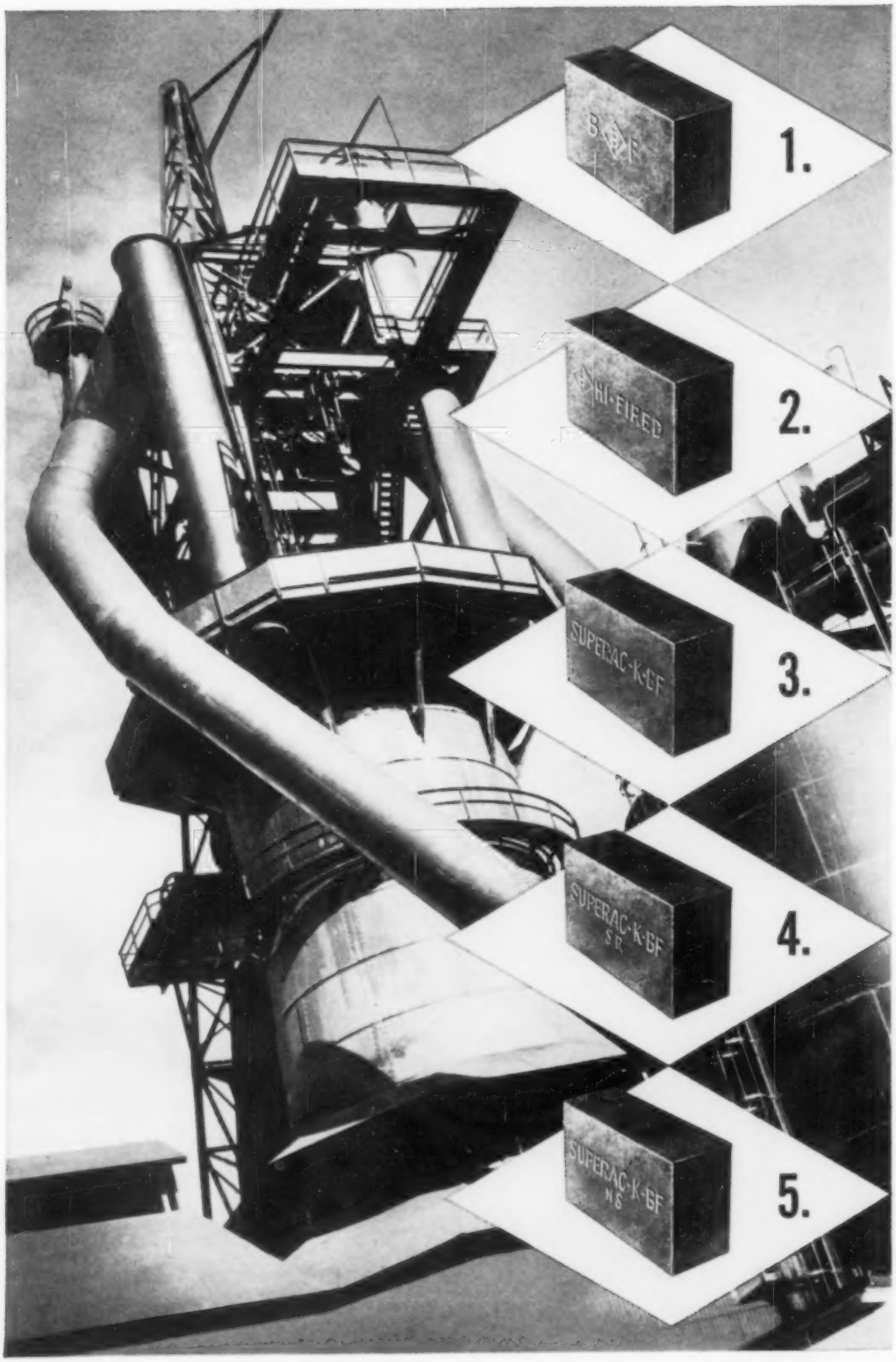
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To meet the increasingly specialized demands of modern iron making, GREFCO now offers five different outstanding blast furnace bricks, each tailored to meet your requirements.

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A mechanized "oracle" is helping Bell Telephone Laboratories predict the future in communications devices and systems.

The oracle is "Sibyl," a computer-like machine developed by Bell Laboratories engineers and psychologists. It can simulate the action of many kinds of communications devices. Through Sibyl, new kinds of telephone service can be evaluated without the considerable expense of building actual equipment. Observing and recording users' reactions to the simulated equipment, Sibyl provides indications of how users would react to proposed new systems features and equipment.

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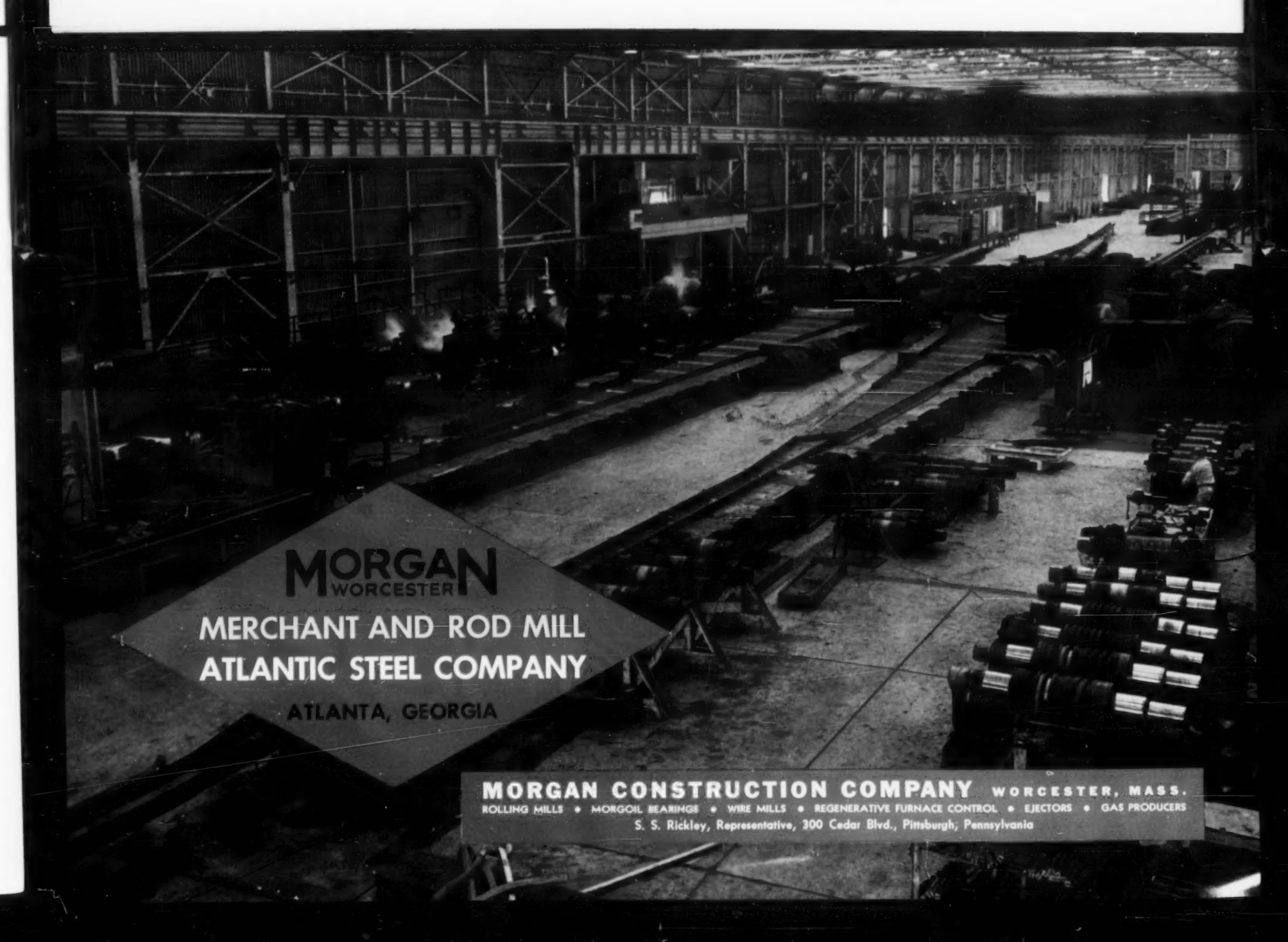
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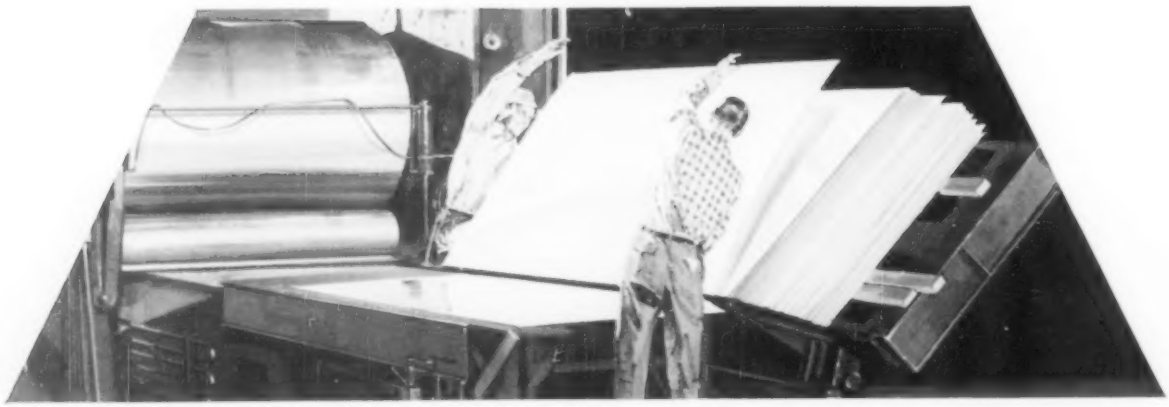

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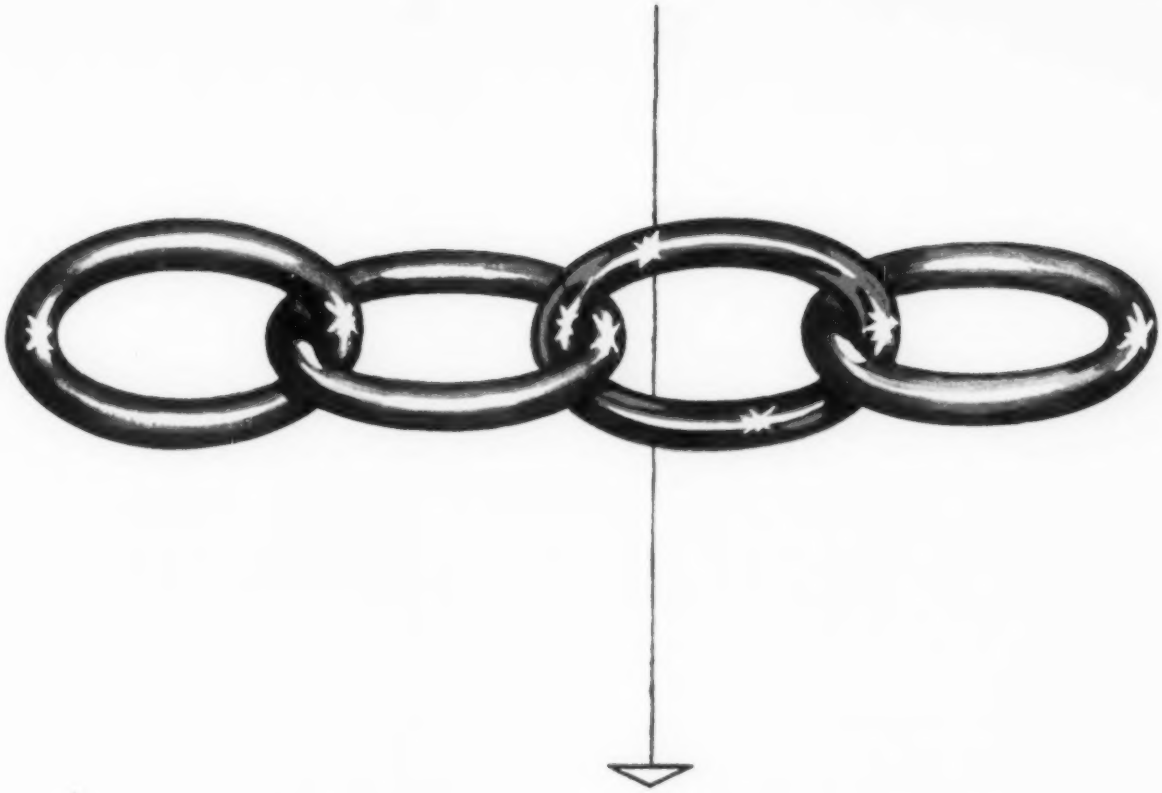

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News of EDUCATION

NUCLEAR FUEL SYMPOSIUM

Columbia University and the Sylvania-Corning Nuclear Corp. have announced plans for the *First International Symposium on Nuclear Fuel Elements*, which will be held Jan. 28-29, 1959, at Columbia University.

Dr. Grayson Kirk, president of Columbia, and Dr. Lee Davenport, president of Sylvania-Corning Nuclear Corp., hope that this meeting will afford the opportunity for an exchange of ideas, in a university setting, on a subject vital for the U.S. "if we are to achieve competitive nuclear power."

Invitations to the meetings will be sent out to ranking researchers and technological experts in the United States, Canada, and the Free World overseas.

Such varied topics as the analyses of different kinds of fuel elements, fabrication techniques, corrosion problems, irradiation and cladding problems, and engineering for low cost fabrication will be included in the sessions.

Prof. Maxwell Gensamer and George L. Kehl of Columbia University School of Mines, along with Stanley B. Roboff and Leonard Smiley of SYLCOR, and Dr. Henry H. Hausner, SYLCOR consulting engineer and secretary of the committee, were named as members of the Symposium.

MATERIALS INFORMATION

The proceedings are now available for the summer courses in *Materials Engineering Design for High Temperatures and Mechanical Properties of Materials*, by contacting: Prof. J. Marin, Department of Engineering Mechanics, The Pennsylvania State University, University Park, Pennsylvania.

NFS AWARDS DEADLINE

The deadline for application for postdoctoral and predoctoral fellowships from the National Science Foundation (NFS) is December 22, 1958 and January 5, 1959 respectively. The Predoctoral Fellowship program provides an annual stipend, payment of tuition and fees, a dependency allowance for married Fellows, and a limited travel allowance.

Candidates must, by the time they enter tenure on their fellowship, have received a doctoral degree in science or the equivalent in scientific training.

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Researchers are needed by the Bureau of Mines for challenging work at many research centers and field laboratories throughout the United States.

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Opportunities are also available for metallurgists, chemists, and chemical engineers at other Bureau experiment stations and laboratories.

Starting salaries range from $4,490 to $10,130 a year.

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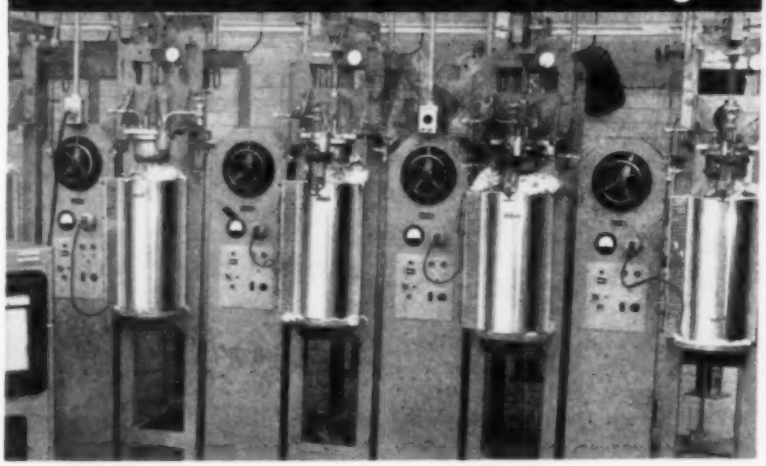
Marshall Furnaces at Oak Ridge



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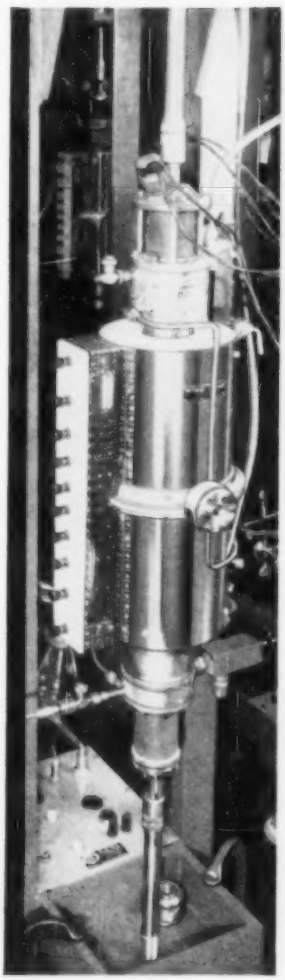

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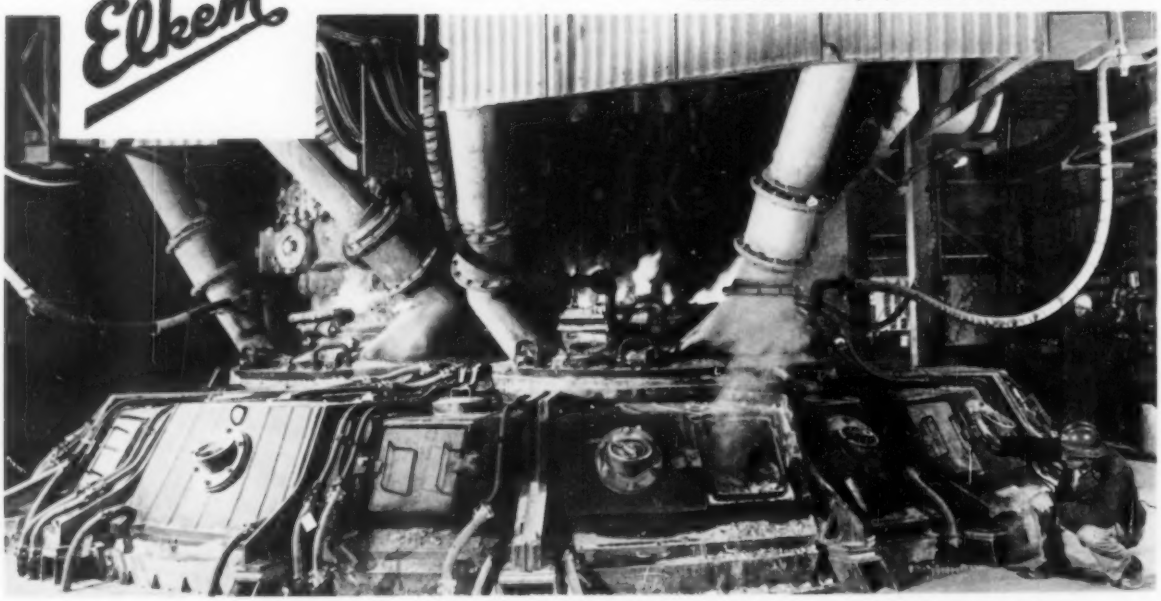
Liquid-metal creep testing frames (shown at top)
Creep frame for testing gaseous environments (left)

Furnace Platform of 1 of 4-39,000 KVA ELKEM CALCIUM CARBIDE Furnaces installed by National Carbide Company at Calvert City, Kentucky

Elkem



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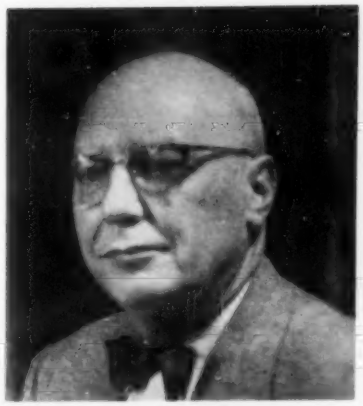
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EFSC Attendance

1943	414	1948	534	1953	749
1944	569	1949	585	1954	882
1945	500	1950	620	1955	949
1946	546	1951	752	1956	979
1947	569	1952	823	1957	1070
				1958	?

Program

Electric Furnace Conference

Statler Hotel, Detroit, Mich.

REGISTRATION

Wednesday, December 3—9:00 am to 9:00 pm—Ballroom Foyer
Thursday and Friday, December 4 and 5—8:30 am to 5:00 pm—Ballroom Foyer

Calendar and Index of Events

WEDNESDAY, DECEMBER 3

Plant Trips: Stainless Steel Division of Jones & Laughlin Steel Corp., and the Rouge Plant of Ford Motor Co.

Chartered buses will leave from the Bagley St. entrance of the Statler Hotel at 1:00 pm. Buses will return to the Statler Hotel by 5:00 pm.

6:30 pm—Parlor E

Business Meeting:

Electric Furnace Committees Annual Dinner and Business Meeting
(All Chairmen of technical sessions are invited to attend)

THURSDAY, DECEMBER 4

Authors and Chairmen Breakfast: 8:00 am—Ivory Room
Authors and session chairmen will meet for breakfast followed by an opportunity to plan final details with regard to the schedule of papers for each session.

ANNUAL DINNER

Thursday, December 4

6:30 pm—Wayne and Bagley Rooms, Reception and Cocktail Party for dinner guests
7:00 pm—Grand Ballroom, Dinner

Toastmaster: K. D. Cassidy, Group Director, Body Group, Ford Motor Co., Dearborn, Mich.

Speaker: M. K. Schnurr, President, Stainless and Strip Division, Jones & Laughlin Steel Corp., Detroit, Mich.

Subject: *Commercial Aspects of Stainless Steels in Our Economy*

9:30 to 9:45 am—Grand Ballroom

General Session

Welcoming Remarks; Salute to Automobile Industry:
By A. C. Ogan, Chairman, Committee for the Sixteenth Annual Conference.

Response:
By V. E. Zang, Chairman, Electric Furnace Committee—Announcements and Reports.

Introduction of Group on Production of Carbides, Alloys, Metals, and Phosphorus in Electric Furnaces:
By R. K. Kulp, Senior Staff Engineer, Technology Department, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

THURSDAY, DECEMBER 4

9:45 am to 12:30 pm—Grand Ballroom

Manufacture of Ferro-Alloys

Chairmen:

R. N. Speer, Vice-President, Operations, Chromium Mining and Smelting Corp., Chicago, Ill.
D. F. Brookland, Vice-President, Operations, Keokuk Electro-Metals Co., Keokuk, Iowa.

1. **Electric Furnace Ferro-Alloy Industry in the United States:**
   Preprinted paper by J. H. Brennan, Chief Metallurgist, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y., H. E. Dunn, Associate Technical Director, Vanadium Corporation of America, Pittsburgh, Pa., and C. M. Cosman, Metallurgical Engineer, Vanadium Corporation of America, New York, N. Y.

2. **Manufacture of Ferrosilicon Alloys:**
   Paper by E. J. Davis, Electric Furnace Superintendent, Interlake Iron Corp., Jackson, Ohio, and A. D. Gate, Technical Director, Beverly Plant, Interlake Iron Corp., Beverly, Ohio.
   Discussion: M. J. Giegel, Chief Metallurgist, Chromium Mining and Smelting Corp., Chicago, Ill., and D. D. Barbor, Member Technical Control Group, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

3. **Casting of Ferro-Alloys:**
   Paper by E. T. Johnson, Production Manager, Pittsburgh Metallurgical Co., Inc., Niagara Falls, N. Y.
   Discussion: L. H. Banning, Project Coordinator, Pyrometallurgical Laboratory, U. S. Bureau of Mines, Albany, Oregon, and P. B. Dettmer, Staff Metallurgist, M. A. Hanna Co., Cleveland, Ohio.

4. **Control of Quality in Ferro-Alloy Manufacture:**
   Preprinted paper by A. F. Sprankle, Technical Director and Assistant Vice President, Vanadium Corporation of America, Cambridge, Ohio.
   Discussion: George Fegan, Quality Control Manager, Chromium Mining and Smelting Corp., Spokane, Wash., and J. J. Furey, Chief Chemist, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

Joint Technical Session

THURSDAY, DECEMBER 4

2:00 to 5:00 pm—Grand Ballroom

Physical Chemistry of Steelmaking

Chairmen:

N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.
R. W. Farley, Director, Process Development, Republic Steel Corp., Chicago, Ill.

1. **Review of Technical Conference on "Quality Requirements of Super Duty Steels," Pittsburgh, May 5-6, 1958:**
   Paper by J. F. Elliott, Associate Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass., and B. M. Shields, Chief Metallurgist, Duquesne Works, U. S. Steel Corp., Duquesne, Pa.

2. **Effect of Vacuum Stream Degassing on Properties of Forging Steels:**
   Preprinted paper by M. A. Orehoski, Research Associate, and J. N. Hornak, Assistant Director, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.
   Paper by A. L. Lehman, Superintendent, Electric Furnace Melting Dept., Bethlehem Plant, Bethlehem Steel Co., Bethlehem, Pa.

3. **Experiences wih Ladle Degassing:**
   Paper by C. W. Finkl, Vice-President, Engineering, A. Finkl and Sons Co., Chicago, Ill.

Ingot Technical Session

FRIDAY, DECEMBER 5

9:30 am to 12:30 pm—Grand Ballroom

Stainless Steel—
Production and Applications

Chairmen:

J. W. Freeman, Professor of Metallurgical Engineering, University of Michigan, Ann Arbor, Mich.
R. Sergeson, Chief Metallurgical Engineer, Stainless Steel Division, Jones & Laughlin Steel Corp., Detroit, Mich.

1. **Present and Future Application of Stainless Steel Products in the Automotive Industry:**
   a. Paper by C. W. Vigor, Senior Metallurgical Engineer, Metallurgical Engineering Dept., Research Lab., General Motors Corp., Detroit, Mich.
   b. Paper by B. O. Burbin, Laboratory Supervisor, Chemical Engineering Lab., Chrysler Corp., Detroit, Mich.

2. **Developments in Melting Operations:**
   Preprinted paper by C. L. Corey, Associate Professor, Department of Chemical and Metallurgical Engineering, Wayne State University, Detroit, Mich.

Castings Technical Session

FRIDAY, DECEMBER 5

9:30 am to 12:30 pm—Michigan Room

Foundry Practices

Chairmen:

A. F. Gross, Research Metallurgist, The Ohio Steel Foundry Co., Springfield, Ohio.
C. G. Mickelson, Assistant Manager, Manufacturing Research Laboratories, American Steel Foundries, Indiana Harbor Works, East Chicago, Ind.

1. **Effect of Various Additions to the Electric Arc and Induction Furnace on Gas Contents:**

   Paper by M. Boris, Research Chemist, American Steel Foundries, Granite City, Ill.

2. **Pinhole Porosity in High-Alloy Steel Castings Made in Green-Sand Molds:**

   Preprinted paper by R. J. Mangone, Research Engineer, A. M. Hall, Division Chief, and C. E. Sims, Technical Director, Battelle Memorial Institute, Columbus, Ohio, and W. T. Bryan, Manager, Custom Product Sales, The Duriron Co., Inc., Dayton, Ohio.

3. **High Frequency Induction Melting of Steel in Furnace Units Up to 5½-Ton Capacity:**

   Preprinted paper by J. T. Gow, Vice President in Charge of Manufacturing and Engineering, and C. F. Hamilton, Production Control Metallurgist, Sandusky Foundry and Machine Co., Sandusky, Ohio.

   Paper by Stephen Marmaroff, Foundry Superintendent, Babcock and Wilcox Co., Barberton, Ohio.

4. **Oxidation and Deoxidation Practice in the High-Frequency Induction Furnace:**

   Paper by Joseph Dewez, General Manager, R. Berger, Chief Engineer, A. Paquot, and P. Nicolaides, Metallurgical Engineers, Societe Anonyme Usiness E. Henricot Court, St. Etienne, Belgium.

Special Arc Group Technical Session

FRIDAY, DECEMBER 5

9:30 am to 12:30 pm—English Room

Manufacture of Calcium Carbide and Other Products

Chairmen:

R. T. Lund, Vice-President, Operations, National Carbide Co., Calvert City, Ky.

L. H. Banning, Project Co-ordinator, U. S. Bureau of Mines, Albany, Ore.

1. **A Brief History of Calcium Carbide Manufacture:**

   Paper by W. J. Fulton, Vice-President and General Manager, Midwest Carbide Corp., Keokuk, Iowa.

2. **Tapping and Casting of Calcium Carbide:**

   Preprinted paper by E. W. McGovern, Assistant Technical Director—Carbide Operations, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

3. **Electric Furnace Production of Special Irons and Titania Slag:**

   Paper by G. E. Wagner, Operating Superintendent, and J. M. Noy, Director of Research, Quebec Iron and Titanium Corporation, Sorel, Que., Canada.

4. **Electrically Smelted Oxides and Metalloids of Zirconium and Titanium:**

Paper by A. J. Hudson, Superintendent of Alloy Department, and A. C. Haskell, Jr., Chief, Process Metallurgy Division, Research Department, Titanium Alloy Manufacturing Division, National Lead Co., Niagara Falls, N. Y.

Discussion: Fred A. Upper, Manager, Product Engineering Branch, Bonded Abrasive Division, The Carborundum Co., Niagara Falls, N. Y.

Ingot Technical Session

FRIDAY, DECEMBER 5

2:00 to 5:00 pm—Grand Ballroom

Melting; Cost Reductions

Chairmen:

W. C. Kollman, Superintendent, Electric Furnaces, Crucible Steel Company of America, Midland, Pa.
R. B. Shaw, General Superintendent Melting, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

1. **Use of Direct Reduced Iron in the Electric Furnace:**

Report by R. W. Farley, Director of Process Development, Republic Steel Corp., Chicago, Ill.
Report by P. U. Gummeson, Vice-President and General Manager, Hoeganes Sponge Iron Corp., Riverton, N. J.

2. **Simplified Calculation of Effects of Oxygen Blowing Rates:**

Paper by G. W. Healy, Section Leader, Metals Research Laboratories, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

3. **Linear Programming the Material Costs of Stainless Steel:**

Paper by D. C. Hilty, Manager, Research Information, R. W. Taylor, Head, Mathematical Analysis, and R. H. Gillespie, Head Computing Laboratory, Metals Research Laboratories, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

Castings Technical Session

FRIDAY, DECEMBER 5

2:00 to 5:00 pm—Michigan Room

Special Operating Technology

Chairmen:

J. W. Tibbits, Assistant Works Manager, Canadian Steel Foundries, Ltd., Montreal, Que., Canada.

N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.

1. **Effect of Phosphorus and Sulfur Content on the Ductility and Toughness of Cast Low Alloy Steels:**

Preprinted paper by John Zotos, Assistant Chief of the Experimental Foundry Branch, Rodman Laboratory, Watertown Arsenal, Watertown, Mass.

2. **Desulphurization of Steel by the Injection of Lime and Aluminum-Magnesium Alloy:**

Preprinted paper by D. E. Parsons, Scientific Officer, and S. L. Gertsman, Chief, Physical Metallurgy Division, Department of Mines and Technical Surveys, Ottawa, Ont., Canada.

3. **Improving Electric Furnace Refractory Life by Special Shell Cooling Techniques:**

Paper by V. J. Howard, Melting Foreman, Oklahoma Steel Castings Co., Division of American Steel and Pump Corp., Tulsa, Okla.

Discussion: W. E. Lewis, Manager, Field Sales, Lectromelt Furnace Division, McGraw-Edison Co., Pittsburgh, Pa.

4. **Split Heat Techniques:**

Preprinted paper by Gordon Pride, Metallurgist, Canadian Unitcast-Steel Ltd., Sherbrooke, Que., Canada.

Paper by S. C. Smith, Chief Metallurgist, Foundry Division, Texas Foundries, Inc., Lufkin, Texas.

Paper by J. W. Tibbits, Assistant Works Manager, Canadian Steel Foundries Ltd., Montreal, Que., Canada.

Paper by N. H. Keyser, Metallurgist, Battelle Memorial Institute, Columbus, Ohio.

Special Arc Group Technical Session

FRIDAY, DECEMBER 5

2:00 to 5:00 pm

Electrode Holders and Planning Session

Chairmen:

R. K. Kulp, Senior Staff Engineer, Technology Department, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

H. S. Newhall, Chief Development Engineer, Engineering and Construction Department, Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

1. **Electrode Holders:**

Preprinted paper by H. S. Newhall, Chief Development Engineer, Engineering and Construction Dept. Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

Discussion: Edward Hnatuk, Vice-President, Engineering, Chromium Mining and Smelting Corp., Chicago, Ill.

E. E. Coleman, Plant Manager, Hanna Nickel Smelting Co., Riddle, Ore.

G. J. Kiedaisch, Superintendent, Midwest Carbide Corp., Keokuk, Iowa.

J. R. Lee, Director of Engineering Design, Vanadium Corporation of America, Cambridge, Ohio.

W. R. Meredith, General Superintendent, Interlake Iron Corp., Beverly, Ohio.

D. F. Brookland, Vice-President, Operations, Keokuk Electro-Metals Co., Keokuk, Iowa

2. **Planning and Organization for Future Meetings**

Up to the beginning of World War I, the American ferro-alloy industry was in its infancy and largely dependent on Europe. During that War, capacity was over expanded. Later recovery and commercial and scientific development have resulted in an industry which in 1957 produced 1.8 million tons of ferro-alloys.

ELECTRIC-FURNACE FERRO-ALLOY INDUSTRY IN AMERICA

by J. H. Brennan, H. E. Dunn, and C. M. Cosman

THE ferro-alloy industry is today an important element of the industrial structure of the United States. Its output is valued at almost half a billion dollars annually and its products are basic not only to National defense but also to the peacetime standard of living.

This has not always been so. The ferro-alloy industry from late in the last century has grown from small beginnings, nurtured by the demand for stronger, tougher materials; by the search for steels capable of absorbing severe impact loads and resisting corrosive media and high temperatures; and also by the need for electrical and electronic specialties. Conversely, the ferro-alloy industry has grown because it developed improved steels and alloys by extensive research, and because it was able to show to steel makers the advantages accruing from the more extensive and the more economical use of alloying elements.

The industry has grown in scope from producing a few grades of ferro-alloys of the more common metals—manganese, chromium, vanadium, silicon, titanium, tungsten, and molybdenum—until there are today some 150 compositions of ferro-alloys available to the steel maker, including such elements as columbium, zirconium, and boron. In 1912 the industry produced 360,000 tons of alloys valued at about $12,000,000, while 1957 production figures show an output of 1.8 million tons worth $440,000,000.

In the United States, the history of an industry is largely the history of the companies making up this industry; hence, this paper will briefly trace the development of the most important ferro-alloy-producing companies.

Quite varied have been the reasons that caused the different companies to move into the ferro-alloy field; the Willson Aluminum Co., seeking methods of producing aluminum, succeeded with the production of calcium carbide, and their developing electric furnace skills led them to the production of ferro-silicon and ferrochromium alloys. Willson was the predecessor of the Electro Metallurgical Co. of Union Carbide. Two Pittsburgh undertakers, interested in vanadium as an alloying agent for steel, set about to find a mine and, ranging as far as Peru, fathered American Vanadium Co., the predecessor of Vanadium Corp. of America. Experiments of the

J. H. BRENNAN is chief metallurgist, Electro Metallurgical Co. div. of Union Carbide Corp., while H. E. DUNN and C. M. COSMAN are with Vanadium Corp. of America. This paper is being presented at the AIME, Electric Furnace Conference, Cleveland, December, 1958.

Electric Reduction Co. to produce magnesium during World War I led to the formation of the Molybdenum Corp. of America which successfully produced a number of ferro-alloys.

Electro Metallurgical Co.

Blast furnace production of ferromanganese, spiegeleisen, and silvery iron was well established in the United States in the last decade of the 19th century. The beginnings of the electric-furnace production of alloy compositions beyond the range of the blast furnace were initiated by James Turner Morehead as an outgrowth of his attempts to establish the production of calcium carbide. The Willson Aluminum Co. at Spray, N. C., working toward the production of metallic aluminum, discovered the electric-furnace method of producing calcium carbide in experiments which were intended to yield metallic calcium. In his expansion of the new industry, Morehead acquired power rights at Holcomb Rock, Va., and at Glen Ferris, W. Va. At Holcomb Rock, du Chalmot produced the first electric-furnace ferrosilicon made in America. A variety of silicon alloys was produced, beginning in 1895. A considerable, early expansion of the ferro-alloy industry, however, came through the production of ferrochromium needed for projectiles and armor plate in the Spanish-American War. Morehead established the production of calcium carbide at Niagara Falls in 1896 and at Sault Ste. Marie, Mich., in 1900. In 1906, the Electro Metallurgical Co. began producing ferro-alloys at Niagara Falls as an extension of its predecessor companies in Virginia and West Virginia.

Frederick Mark Becket joined the Niagara Falls organization in its beginnings, and his early work resulted in the silicon reduction methods employing silicon or silicides for the production of low-carbon alloys, particularly low-carbon ferrochromium. Variants of Becket's methods are still used for the bulk of the low-carbon ferrochromium produced today.

During World War I, Electro Metallurgical Co. was producing all types of ferro-alloys used by the steel industry, including ferrosilicon, ferrochromium, ferromanganese, ferrovanadium, ferromolybdenum, ferrotungsten, and siliconzirconium alloys.

During the early thirties the Electro Metallurgical Co. started installing both hydro-electric and thermal power in West Virginia, and a ferro-alloy plant came into production in 1932 at Alloy, W. Va. Subsequently, plants were built at Sheffield, Ala., in 1940; at Portland, Ore., in 1941; at Marietta, Ohio, in 1951; and, for the United States government, a ferrosilicon and magnesium metal plant at Spokane, Wash. in 1942 and at Ashtabula, Ohio, in 1943. The Ashtabula plant was acquired by Electro Metallurgical Co. from the Government in 1946.

At Marietta, Ohio, an innovation in the production of very low-carbon ferrochromium started with the Erasmus-Bagley process for the vacuum decarburization of ferrochromium in a solid state reaction. Here, too, the operations were broadened in the pure metal fields with the installation of electrolytic plants for chromium and manganese. At the Ashtabula, Ohio, plant the production of titanium metal by sodium reduction was instituted in 1956.

Vanadium Corp. of America

Vanadium Corp. of America owes its inception to the discovery of vanadium deposits in the Peruvian Andes in 1905 to 1906 and the chance meetings of the Flannery brothers of Pittsburgh with metallurgists and South Americans that caused them to become interested in supplying Peruvian vanadium to the United States' steel industry. As a result, James M. Flannery went to Peru in 1906 to negotiate with a Señor Fernandini, who controlled the then recently discovered vanadium deposit at Mina Ragra. He had to act fast to obtain an option, since other interests were competing for the property. With a flair for drama, Flannery won out by converting his capital into gold pieces and spreading them before the Peruvian. That was the beginning of the American Vanadium Co.

The availability of a source of vanadium came just in time to meet the demand for this alloying metal which arose from the use of vanadium steel in automobile construction. Henry Ford in particular believed in the value of vanadium-containing steel in this application and placed large orders with the steel mills.

It was, however, a far road for the ore to travel from the heights of the Andes to the United States' automobile plants, not only geographically, but also technologically. Product problems beset the operations of the American Vanadium Co., until B. D. Saklatwalla, who joined the company in 1909, designed methods of extracting vanadium from ore and special electric furnaces to produce ferrovanadium. A new plant and laboratory were put up at Bridgeville, Pa., near Pittsburgh.

In 1919 Vanadium Corporation of America was organized and acquired the properties of the American Vanadium Co. It expanded from a single product operation by acquiring, in 1924, the assets of the U. S. Ferro Alloys Corp., which included important facilities at Niagara Falls. This plant had been established by Robert Turnbull, who was an early leader of the ferro-alloy industry. At Niagara Falls, Vanadium Corp. of America produced ferrochromium, chromium-silicide, and ferrosilicon, as well as other products.

Another important step in the development of the Vanadium Corp. of America was the introduction into the United States of the French Perrin process for the production of ferrochrome of low-carbon content. To manufacture this product, large, new facilities were provided at Graham, W. Va., in 1953 and at Vancoram, near Steubenville, Ohio, in 1958. The obsolete facilities at Bridgeville have been abandoned and replaced by a modern plant and research center at Cambridge, Ohio, which began to operate in 1953.

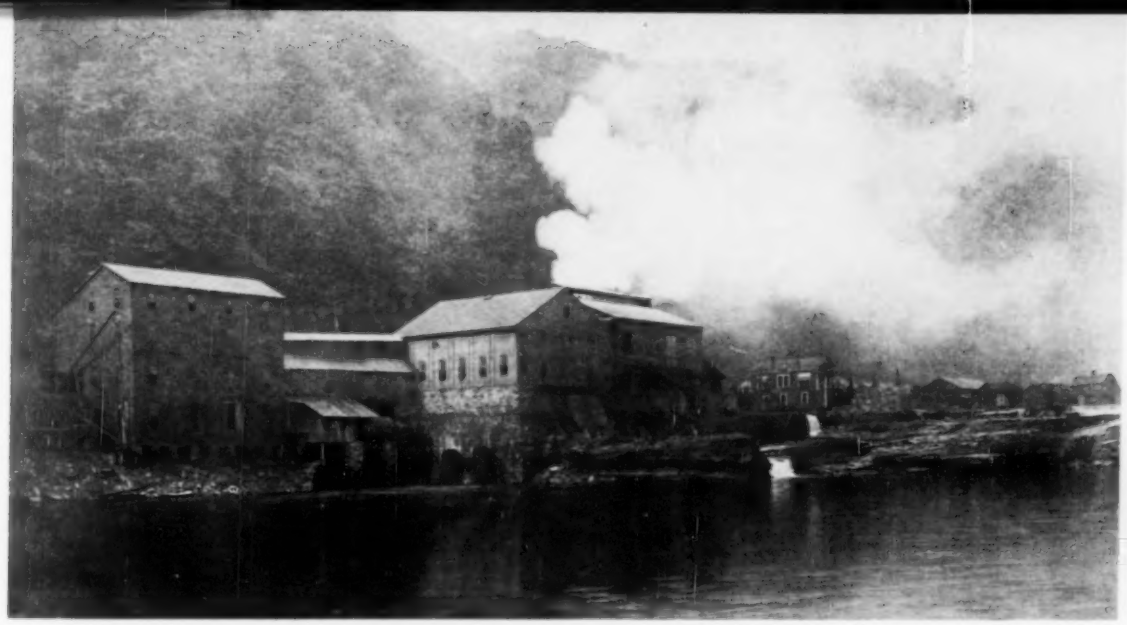
Vanadium is a co-product of uranium in many United States' ores. The significance of the Peruvian vanadium deposits declined as the Vanadium Corp. of America became more extensively engaged in domestic mining.

Titanium Alloy Mfg Co.

Titanium Alloy Co. was established in 1906 to develop the patents and processes of Auguste J. Rossi relating to titanium and its compounds.

The production of ferrocarbotitanium was undertaken in an electric-furnace plant at Niagara Falls, and the product found extensive application in the manufacture of steel rails, especially from bessemer steel. This application declined when open-hearth steel took over, but titanium found other uses in the manufacture of special steels.

In 1948 the company became the Titanium Alloy Mfg. Div. of National Lead Co. It operates mines in



Early view of Electro Metallurgical plant at Kanawha Falls, Glen Ferris, W. Va.

Florida and Australia and produces titanium- and zirconium-base products for a great many industries.

Pittsburgh Metallurgical Co.

Pittsburgh Metallurgical Co. was established in 1913 and built a reduction facility at Monaca, near Pittsburgh. During World War I, the local power company refused to provide sufficient electrical energy, and the plant had to shut down. As a result, the company moved to Niagara Falls in 1919. This plant has expanded from its original three furnaces to a current capacity of eight.

In 1941 a new plant was established at Charleston, S. C., with four furnaces. This facility now comprises 11 units.

A further plant, added by the company in 1949 at Calvert City, Ky., originally consisted of three furnaces. Later expansions have brought the equipment to a total of 12 units. This plant is the most modern and largest of the company.

Products of this company include silicomanganese, ferrosilicon, ferrochromium, and ferrochrome-silicon.

Molybdenum Corp. of America and Keokuk Electro Metals Co.

In 1915 a group of consulting engineers formed the Electric Reduction Co. This company failed in its attempt to produce magnesium by a distillation process, but it then began to reclaim tungsten from high-speed steel scale, and later expanded this operation to smelt ferrotungsten and ferromolybdenum from ores and concentrates at Washington, Pa.

About 1920 a substantial molybdenum property was acquired at Questa, N. M., and the name of the company was changed to Molybdenum Corp. of America. Recent exploration by Molybdenum Corp. has resulted in a very large expansion of their ore reserves at Questa.

About 1951 a huge deposit of rare earths was acquired and a number of interesting applications of these elements to steel manufacturing problems were developed. As far as is known, the deposit represents the major world source for rare earths.

Keokuk Electro Metals Co. started the manufacture of ferrosilicon at Keokuk, Iowa, in 1916. In 1948, they acquired Government facilities at Wenatchee, Wash., which had been constructed in 1942.

Keokuk is a producer of ferrosilicon, ferrochromium, and silicon metal.

Climax Molybdenum Co.

During World War I, which stopped the flow of molybdenum to the United States and stimulated demand, attempts were made to develop a domestic source of supply. Accordingly, the Climax Molybdenum Co. was founded in 1917-1918 to exploit the long-known, huge Bartlett Mountain deposit. Climax soon could assure the world markets of a continuous supply of molybdenum from a single source and was ready for business.

Business, however, was not ready for Climax; the advent of peace left the company without a market. Then an extensive sales development program was launched, and, as a result, molybdenum began to be used in many new alloying applications that have remained major outlets. Mining was resumed in 1924, and conversion operations began in 1926 at Langeloth, Pa., where production facilities for ferromolybdenum and other molybdenum products were provided. Since then, Climax's single mine has accounted for between one-half and two-thirds of the world's output of molybdenum. The hundred millionth ton of ore was mined in February 1957, and known reserves of ore are sufficient for decades to come.

Climax's position in the ferro-alloy field has been based on molydenum. However, a byproducts recovery plant, installed in 1948, permits recovery of associated mineral values, including tungsten. In 1950, Climax diversified by moving into the mining and milling of uranium-vanadium ores.

The company has successfully developed molybdenum from a rare metal to one of the most important steel alloying elements, as well as for many other uses. It was merged in 1957 with the American Metal Co., Ltd., under the name of American Metal Climax, Inc., retaining its identity as a division.

Ohio Ferro-Alloys Corp.

Ohio Ferro-Alloys Corp. had its beginning in 1927 when a number of industrialists of Canton, Ohio, formed the Electric Pig Iron Corp. and built a small electric furnace at Philo, Ohio. They first made ferrophosphorus and then, in 1928, adopting the present name for the enterprise, started producing ferro-alloys.

By 1941 the company was operating a second plant located at Tacoma, Wash., on behalf of the United States government. Again, in 1951, the Corporation expanded by building a plant at Brilliant, Ohio, and in 1958 a new plant at Powhatan Point, Ohio, was opened. The Corporation produces a full line of silicon, chrome and manganese ferro-alloys.

Chromium Mining & Smelting Corp.

In 1929 Robert Turnbull founded Algoma Smelting Co. at Sault Ste. Marie, Ontario, Canada, in cooperation with Francis Fitzgerald and Peter Bennie, to produce ferro-alloys. In 1934 Algoma was taken over by Chromium Mining & Smelting Corp. which was originally organized to process low-grade domestic chrome ores. Developing the processes of M. J. Udy, the company entered the field of exothermic alloys.

In 1947 additional processing facilities were completed at Riverdale, Ill., for the production of exothermic products, followed by the leasing from the United States government of the idle magnesium plant at Spokane, Wash., in 1948. This plant, run by the subsidiary, Pacific Northwest Alloys, Inc., was originally used to supply metal for the Riverdale unit and was later converted to the production of low-carbon ferrochrome.

In 1951 an arc furnace plant was built by another subsidiary, the Montana Ferro Alloys Corp., at Woodstock, near Memphis, Tenn., for the production of standard chromium and silicon alloys.

Tennessee Products & Chemical Corp.

In 1940 Tennessee Products, which had been producing pig iron, charcoal, coke, and chemicals, began production of blast furnace ferromanganese at Rockdale, Tenn. Operations were soon expanded by the addition of electric furnaces and the manufacture of ferrosilicon. Further blast furnace manganese facilities were acquired at Rockwood, Tenn. in 1942. With the end of World War II, operations were reorganized and continued only at Rockwood. In 1947 the company adopted the name of Tennessee Products & Chemical Corp. and purchased the Southern Ferroalloys Co., which had two electric furnace plants at Chattanooga, Tenn., making ferrosilicon and ferromanganese. It was while working at Southern Ferroalloys that Andreae conceived his theory of electroperipheral resistance, now known as *Andreae's ratio*.

A subsidiary, the Tenn-Tex Alloy & Chemical Corp., was formed together with Texas steel interests shortly thereafter, and three submerged arc furnaces were built at Houston, Texas, where ferromanganese has been produced since 1952.

Late in 1955 construction of the Roane Electric Furnace plant at Rockwood was started, and operation began in August, 1956. The plant has eight submerged-arc and four tilting furnaces making alloys of manganese, chrome, and silicon.

Interlake Iron Corp.

In 1955 Interlake Iron Corp. acquired the assets of the Globe Iron Co. Globe was founded in 1872 and engaged primarily in the manufacture of silvery pig. Although Globe installed an electric furnace as early as 1933, the amount of power available at Jackson, Ohio, was inadequate to sustain a full-size electric-furnace operation. In 1952, sufficient power became available, and an electric furnace was installed to produce ferrosilicon. The construction of a new plant was undertaken in 1954 at Beverly, Ohio, which now comprises four furnaces for the production of ferrosilicon, ferrochrome-silicon, high- and low-carbon ferrochrome, and silicomanganese.

Other ferro-alloy producers

About the end of the 19th century, Theo Goldschmidt developed the possibility of substituting aluminum for carbon in the reduction of iron and other metallic oxides. This process, originally intended for welding purposes, was introduced from Germany into the United States by the Goldschmidt Thermit Co., which was formed in 1904. A substantial volume was achieved during World War I when the method was applied to the production of chromium, manganese, vanadium, and tungsten alloys. Today the principal alloy produced by Metal and Thermit, the successor to the original company, is ferrotitanium, as well as chromium metal and minor amounts of ferroboron.

The Anaconda Copper Co. has been an intermittent producer of electric-furnace ferromanganese since World War I, basing their operations on Montana ore.

Hanna Nickel Smelting Co. at Riddle, Ore., has adapted the electric furnace to the production of ferronickel from low-grade garnierite ore. This installation began operations in 1954.

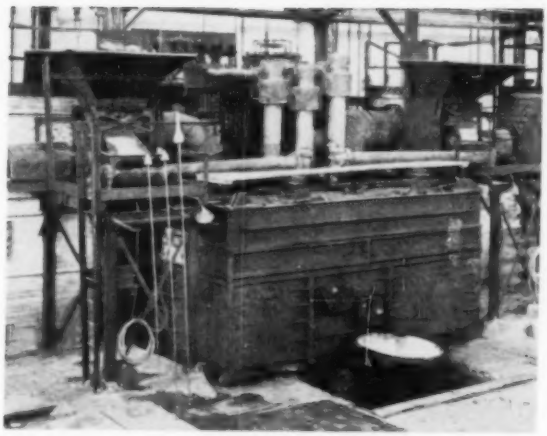
E. J. Lavino & Co., which is an important producer of ferromanganese, recently celebrated their 70th anniversary as a company. When they purchased four blast furnaces in the Lebanon Valley of Pennsylvania and in Virginia at the beginning of World War I, they became the first non-captive producers of ferromanganese in this country.

On occasion, the major steel producers have all made blast-furnace ferromanganese for home consumption; US Steel and Bethlehem have produced it continuously.

The industry as a whole

In the foregoing, the history of the more important companies of the United States' ferro-alloy industry has been described briefly. A good many of them have not only grown enormously since they were first established, but have also changed their name and character. During the lean periods they have lost many competitors, and these companies are the survivors. But there have been many more that are now only names and memories, and yet many of them have made substantial contributions to the art, for it is the men that make the companies.

The ferro-alloy industry is based upon the important discoveries of men, such as Sir Humphrey Davy who produced the first continuous arc in 1800, and Sir William Siemens, who operated the first direct and indirect arc furnaces in 1878. Henri Moissan experimented with the electric arc 12 years later and produced most of the metals, carbides,



Electric furnaces of World War I era at Bridgeville plant of America Vanadium Co., now Vanadium Corp. of America.

borides, and silicides made today. His publication *The Electric Furnace*, published in 1897, summarized his researches and gave impetus to the development of the electric-furnace industry. His student, Heroult, based his successful arc-furnace design on these experiments. Then followed the great French metallurgists, Gin and Coutagne, and the German, Goldschmidt, who established the metallurgy of ferro-alloys based on the electric furnace and on aluminothermy.

Up to the beginning of World War I, the American industry was in its infancy and largely dependent on Europe. Nevertheless, Andreae, Becket, du Chalmot, Morehead, Price, Rossi and Saklatwalla, and Tone and Turnbull, were even then pioneering new processes.

It was World War I that established a domestic ferro-alloy industry; until 1914, substantial amounts of ferro-alloys were imported from Europe. During that War, capacity for the production of ferro-alloys was so expanded that at its end many companies had to close down, while some took up the manufacture of other products.

In 1914 there was only one American company making ferrosilicon; in 1917 there were five. A similar growth pattern is indicated for ferrochrome. During World War I ten different firms made ferrovanadium and only six lasted into the peace.

It was the rumor that the Germans were using molybdenum in their heavy guns that caused a feverish search for sources of supply in the United States, and brought about our dominant world position in this metal.

A sizeable stock of zirconium ore was assembled on the basis of a similar rumor, relating to the use of zirconium in light armor plate. When it was turned over to Dr. Becket, he solved the difficulties of production within two months, and substantial quantities of the hitherto unknown ferrozirconium became available.

The post World War I adjustment in the Twenties caused many fatalities among United States' ferro-alloy companies and saw the ferro-alloy industry established in locations where cheap power was available. Up to the end of World War II the industry placed its plants near hydro-electric stations. Since then, they have moved to places where cheap thermal power can be obtained.

A slow recovery began only about 1924. From 1928 on, the growth of the molydenum industry was nothing short of spectacular. Actually, the ferro-alloy industry as a whole suffered less during the depression of the thirties than the steel industry, a testimony of the increased significance of alloy steel.

World War II was a period of new growth in the industry, and under Government sponsorship it was more orderly and organized than in 1914-1918. The wartime and postwar demand for ferro-alloys has raised US productive capacity to the highest point in history.

The availability of low-cost oxygen after World War II has occasioned considerable modifications in steelmaking. The ferro-alloy industry has felt the effects of this development in the changed pattern of raw material requirements in the production of stainless steel.

From the point of view of the ferro-alloy industry, the most significant development of these war years was the introduction of vacuum technology on an industrial scale. New processes have been based on this advance not only for making low-carbon ferrochromium pellets, but also in producing high-purity metals, such as columbium, zirconium, and titanium.

The utilization of minute additions of elements to achieve specific effects has brought about the application of small amounts of boron, magnesium, and rare earths in ferrous metallurgy. A concurrent trend has been the introduction of new dimensions in purity requirements. Also the requirements of the atomic energy program have resulted in the development of ultrapure metals. Such techniques are being applied to special problems in ferro-alloy metallurgy, and are now used also to meet the requirements of the new titanium and zirconium industries, among others. As a result there has been a considerable re-equipping of production facilities of the ferro-alloy industry especially with vacuum and consumable electrode furnaces.

Conclusions

No history of the United States' ferro-alloy industry should be closed without paying special tribute to the pioneers who laid its technological foundations.

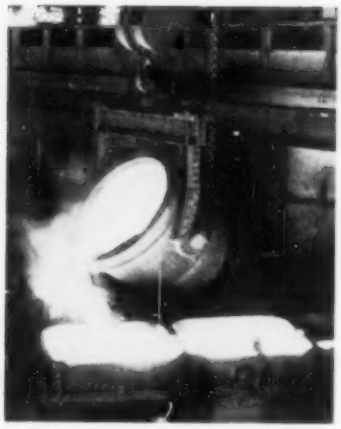
James Turner Morehead established the industry in Spray, N. C., and later at Holcomb Rock, Va., and Glen Ferris, W. Va., at the end of the last century. His pioneering efforts still endure in the current operations of Union Carbide and Electro Metallurgical Co.

Frederick Mark Becket devised the silicon reduction processes for the manufacture of the low-carbon alloys of the strong carbide formers. His basic method was of extreme importance in the development of stainless steel.

Frank Jerome Tone was the first to produce elemental silicon in the electric furnace. While most of his technical contributions were made in the abrasive industry, his early work was of great importance to the developing ferro-alloy industry.

Byramji Saklatawalla developed the extraction and smelting of vanadium from its complex ores and made numerous and significant contributions to the ferro-alloy industry.

MANGANESE and CHROME ORE OUTLOOK



by John M. Warde and Eileen P. Burke

ORES of manganese and chrome have a high order of strategic importance: both metals are basic to the metallurgy and usefulness of steel, the fabric on which our economy rests. Looking beyond the current recession and short-range picture of oversupply in these ores, this review attempts to answer the following questions regarding the long-term outlook for these key commodities: By 1970, what will be the probable demand here and abroad, what are future supply prospects, and what effect is the USSR likely to have on the world market? (See summary forecast on facing page.)

Manganese Ore

The steel industry accounts for the consumption of about 95 pct of the world output of manganese ore, mainly in the production of ordinary carbon steel. The balance—ores of special grades—is essential for use in dry cells and chemicals. Because of the relatively small tonnages, they have not been considered in this review.

At present, there is no commercial substitute for manganese in steel making. Aptly called the *scavenger metal*, its chief function is to minimize the harmful effect of sulfur on the rolling and forging properties of the ingot. It also serves as a deoxidizer, and as an alloy additive it improves the strength and toughness of steel. In U. S. practice, about 13 lb of manganese is added in the open-hearth process for every short ton of steel produced. This manganese is principally in the form of ferromanganese, an alloy containing 70 to 80 pct Mn, obtained by smelting high-grade manganese ore in blast or electric furnaces. The Free World managanese supply problem centers around the ore required for this ferromanganese production. While the preferred ore for metallurgical use should contain 48 pct or more Mn, and meet other chemical and physical specifications, no single ore is generally considered ideal. Normally several ores are blended in the furnace charge for ferromanganese production to give the desired characteristics.

Demand: As steel production goes, so goes manganese ore consumption. This is illustrated by the figure on p. 791, which gives the historical pattern of steel and manganese ore production in the Free World from 1929 to 1956 with estimates through 1970. The average annual growth rate projected for steel in the U. S., 1954-1955 base, is 3 pct, compared with 5 pct for the rest of the Free World. These estimates are based on an assessment of forecasts by various U. S. steel industry observers.

If steel production reaches the levels forecast by 1970, Free World demand for manganese ore for metallurgical use could grow to 9.3 million long tons of the grade now being used (46 pct Mn average). This is almost double the 5.2 million long tons estimated to have been consumed in 1956. U. S. share of the Free World demand could drop to 33 pct by 1970, compared with 39 pct in 1956, if the growth rates projected for steel production in the U. S. and the rest of the Free World are attained.

Table I shows U. S. manganese ore statistics for 1957, compared with 1956. Currently, the manganese ore market is in the doldrums reflecting the reduced level of output of the U. S. steel industry.

TABLE I. U. S. Manganese Ore Statistics
(Thousands of long tons)

	1956	1957
Production (Shipments)	309	325
Consumption	2,122	2,106
Imports	2,120	2,780
Stocks	1,147	1,392

Source: United States Bureau of Mines, Mineral Industry Surveys.

J. M. WARDE is mineral economist and E. P. BURKE is statistical analyst, Mineral Survey Dept., Union Carbide Ore Co., New York City. From a paper presented to the New York Section, AIME.

Future Outlook to 1970

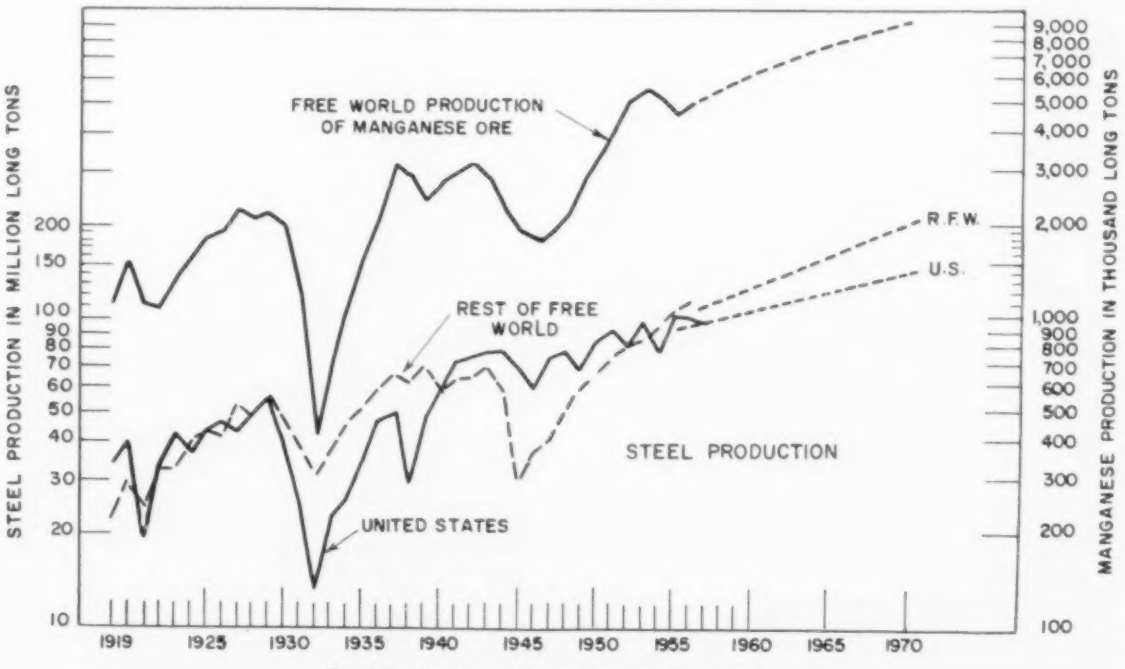
- World demand for both manganese and chrome ores is expected to increase.
- European consumption rates for both chrome and manganese are expected to grow faster than the U. S.
- The drive for industrialization and conservation of resources for home use in major Free World manganese and chrome ore producing countries will increase.
- Free World sources for manganese will remain as at present except for increases in tonnage anticipated from Brazil, new production from French Equatorial Africa, and the emergence of USSR as a principal supplier.
- Supplies of lump metallurgical chrome ore from Free World sources are expected to decline—industry will be forced to greater use of friable ores and fines. The USSR is expected to increase exports of metallurgical ore to the Free World.
- Refractory chrome ore supplies from the Philippines and Cuba will decline—refractory producers will look mainly to Africa.
- The Transvaal will continue to be the principal Free World source of chemical grade chrome ore.
- Research on the economic utilization of low-grade manganese and chrome resources in the U. S. will be intensified.

Reserves: World reserves of manganese ore suitable for direct shipment or for shipment as high-grade concentrates after beneficiation, are estimated by the U. S. Bureau of Mines at a billion tons of which two-thirds are in the USSR. The remainder is in India, Africa, and Latin America. In addition, there are large resources of low-grade manganese which could become important if advances in technology permit their economic exploitation. It is important to note that, with the exception of the USSR, not one of the great industrial nations has adequate, presently-usable reserves of manganese ore.

Free World Trade: Because of the bulky nature of manganese ore, transportation is a big factor. Inadequate rail and port loading facilities in the producing countries have, in the past, been serious obstacles to expanding production. Manganese ore generally moves over long sea routes, hence transport costs are important in determining the consumer price for manganese ore. In the case of the United States, approximately one-third of the average price of manganese ore delivered to the Eastern Seaboard is chargeable to ocean freight. Because such a large proportion of the final cost is transport, deliveries are highly sensitive to changes in shipping rates.

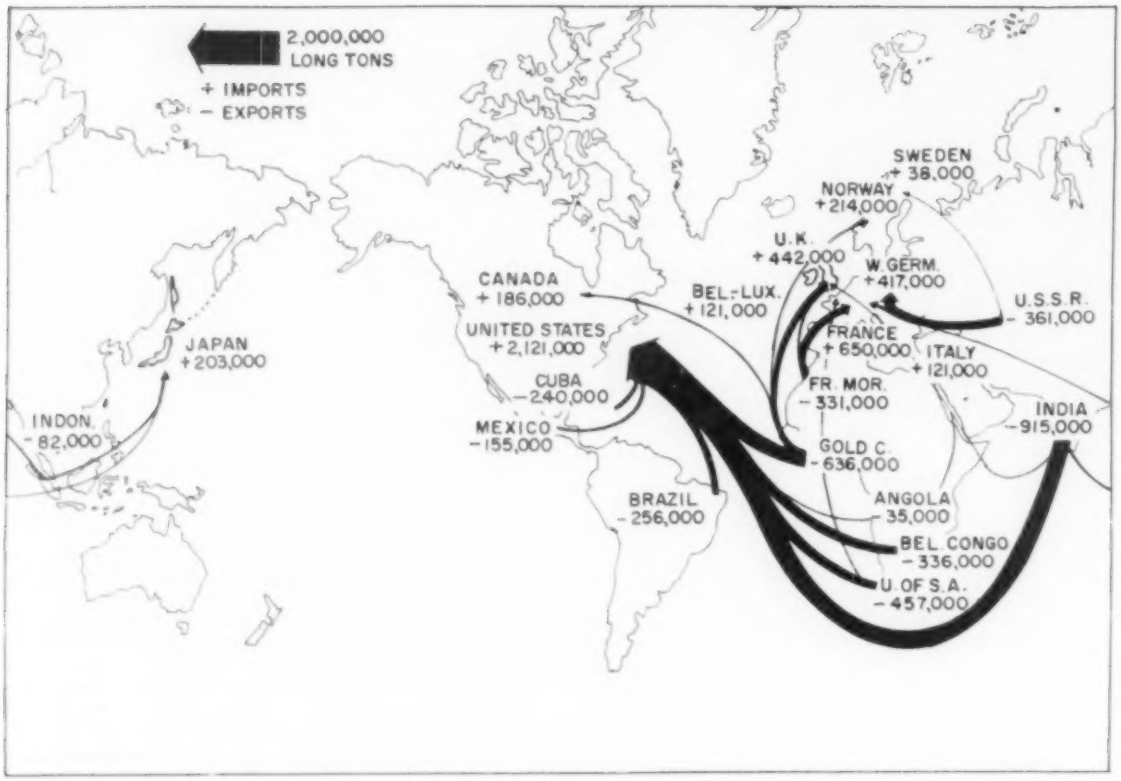
Supply: Free World production of manganese ore in 1957 amounted to about 6 million tons, mainly in Brazil, India, Union of South Africa, and the Belgian Congo. Of historical importance was the emergence of Brazil in first place as a Free World manganese ore source in 1957. The bulk of this output was from the Amapa deposit, jointly owned by Bethlehem Steel and Brazilian interests, located 170 miles up the Amazon in northern Brazil.

The Free World peacetime outlook for manganese ore supplies is good. In addition to the continuing supplies expected from current Free World sources, there is a good possibility that substantial new supplies will be developed in Brazil and Africa within the next decade. U. S. Steel is active in a joint venture with Brazilian interests in the development of the Urucum deposit in western Brazil and is also



Steel Production vs Manganese Ore Production

NOTE: Free World excludes data from USSR and countries in Soviet sphere; includes data for these areas prior to their entry into the Soviet bloc. SOURCES: American Iron and Steel Institute; USBM Manganese Survey (1952), Mineral Industry Surveys, Minerals Yearbook; American Metal Market "Metal Statistics"; Stanford Research Institute "Chemical Economics Handbook".



World Trade in Manganese Ore 1956, Long Tons

SOURCES: Quin's Metal Handbook; Alexander Gakner, USBM; Statistical Summary of the Mineral Industry 1951-56, Published by Overseas Geological Surveys, London; USBM Mineral Industry Surveys; U.S. Department of Commerce.

interested in a joint venture with French interests in the development of an extensive deposit in French Equatorial Africa.

There is an increasing tendency in ore producing countries, notably India and the Union of South Africa, toward industrialization and conservation of resources for home use.

U. S. Position: In 1957, 98 pct of the U. S. manganese ore requirements for metallurgical use were satisfied by foreign ores. U. S. imports of metallurgical grade manganese in 1957 totalled 2.8 million long tons and came mainly from Brazil (30 pct), India (25 pct), Ghana (10 pct), Union of South Africa (8 pct), and Mexico (7 pct). The remaining 20 pct came from 22 other countries.

U. S. duty on manganese ore is ¼¢ per lb of contained manganese from most countries; 1¢ per lb of contained manganese from USSR and Soviet bloc countries; manganese from Cuba and the Philippines is duty free.

Domestic mine shipments, heavily dependent on Government support, reached a peak of 325 thousand long tons of manganese ore containing 35 pct or more Mn in 1957. This output came mainly from Montana, Nevada, and Arizona. Shipments of low-grade manganese containing 10 to 35 pct Mn in 1957 totalled 2700 long tons, all of which came from Montana and New Mexico. Practically all of the domestic shipments went to Government stockpiles. Under normal conditions it is not expected that the present domestic output can increase substantially.

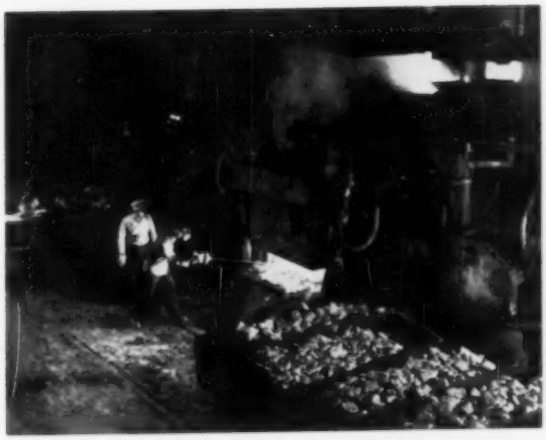
The U. S. has resources of manganese in South Dakota, Maine, Nevada, Minnesota, and Oregon, which, while large in terms of contained metal, are too low in grade for present commercial use. In addition to these resources, the manganese content of the wasted portion of open-hearth slags produced in the U. S. steel industry offers an important additional source of manganese should its economic recovery become possible. The strategic and critical importance of manganese and our heavy reliance on foreign supplies points up the need for continued research to develop acceptable methods for utilizing these domestic resources.

Position of the USSR*: The USSR, once a major U. S. manganese source, is believed to be the world's largest producer of manganese ore. Output in 1955 was reported to be about 4.7 million tons, of which 3.5 million tons were consumed within the USSR in blast furnaces in the production of pig iron and ferroalloys.

* Based on information supplied by Alexander Gakner, East European Specialist, U.S. Bureau of Mines. Also applies to the USSR position on chrome ore.

Exports to Free World countries in 1955 from the Soviet Union totalled about 350,000 tons which went mainly to the United Kingdom, France, and Scandinavia. The balance of the production went to Soviet bloc countries and Soviet stockpiles. About 90 pct of the output comes from two areas: Chiatura in the Caucasus and Nikopol in the Ukraine.

The USSR consumes about 70 lb of manganese per short ton of steel produced. Unlike U. S. practice, about two-thirds of the manganese goes into pig iron used for steelmaking and one-third into ferromanganese for addition in the open hearth. The principal reason for this large consumption of manganese is the high sulfur content of iron ores and



Close-up of a 20-ton electric furnace in which a heat of 25-20 stainless steel is being made.

Finished ferro-alloys in stockpiles are being prepared for shipment.

coke used in the USSR and also because manganese is used as a substitute for alloying metals in short supply. The reserves of the USSR are very large and can maintain production at present or even expanding levels for many years. However, unless consumption rates are substantially lowered, most of the output will be consumed within the Soviet orbit as its steel production continues to grow.

Soviet plans call for increases in iron and steel production of 7 to 10 pct annually. In order to reduce the tonnage of manganese required, efforts are being intensified to decrease the sulfur content of the iron ore and coke and to modernize and expand manganese ore production, as well as recover manganese from high manganese-bearing blast-furnace slags.

A new 400-ton per hr beneficiation plant for manganese ore is being installed at Chiatura to replace some 17 of its antiquated plants. This will increase recovery and improve quality. The use of sintered iron ore, from which much of the sulfur is removed, is being expanded. Further, a new combination heavy media and centrifugal concentrator has been designed which the Soviets say will remove about 80 pct of the ash and 50 pct of the sulfur from most coals.

Whether increased production and advances in technology will free more Soviet manganese for export is difficult to forecast. It is considered that the balance between USSR supply and demand will be maintained, and exports to Free World countries should continue at about the 300,000 to 350,000-ton level for the next few years. Barring deliberate dumping as part of a campaign of economic competition, any increase in exports is expected to be gradual.

Chrome Ore

Chrome ore is consumed in three industrial fields indicated by the traditional trade descriptions of the ore as metallurgical, refractory, or chemical. These grades are based on physical and chemical characteristics; however, because of technological advances, they are interchangeable to a certain extent.

It is estimated that about 65 pct of all the chrome ore consumed in the Free World is employed for alloying purposes, approximately 25 pct goes into refractories, and the remainder is used in chemical manufacture.

The largest metallurgical use of chrome is in the manufacture of stainless steel. Chrome refractories are used mainly in the steel industry for construction and maintenance of open-hearth furnaces. Chrome chemicals are largely used in the pigment, metal treatment, and tanning industries.

There are no known substitutes for most metallurgical and chemical uses of chrome. However, for refractory purposes, magnesite can be substituted for chrome ore for many applications, but at additional cost to the consumer.

Demand: The salient statistics on chrome ore in the United States for 1957, compared with 1956, are given in Table II. Chrome ore consumption, like manganese, is currently at a low level owing to the reduced output of steel in the United States.

Free World peacetime demand for chrome ore for all uses could go to 5 million tons by 1970, approximately 1.8 times the estimated consumption in 1956. This growth is predicated on: 1) the anticipated rise in stainless steel output; 2) increased requirements for refractories to meet the expanding needs of the steel industry; and 3) anticipated increase in the consumption of chrome chemicals.

TABLE II. U. S. Chrome Ore Statistics
(Thousands of long tons)

	1956	1957
Production (Shipments)	145	147
Consumption	1,649	1,572
Metallurgical	1,082	1,051
Refractory	424	388
Chemical	143	133
Stocks	1,095	1,446

Source: United States Bureau of Mines, Mineral Industry Surveys.

The growth of metallurgical requirements for chrome ore may be expected to parallel closely the demand for stainless steel, as indicated by the history of the consumption of metallurgical chrome in the U. S., shown below. If, in accordance with the opinions of various observers, stainless steel production grows at an average annual rate (1955 base) of 6 pct for the United States and 11 pct for the rest of the Free World, by 1970, chrome ore requirements for metallurgical use in the Free World could reach approximately 3.4 million tons. This represents a two-fold increase over the apparent consumption of 1.6 million long tons in 1956. If stainless steel is produced at the projected rates, the U. S. share of this demand will be about 42 pct by 1970, compared with 67 pct in 1956.

The bulk of the chrome refractories used in the steel industry is composed of chrome ore with widely varying additions of sintered magnesite. Because chrome is considerably cheaper than sintered magnesite, it is normally used in the maximum percentages feasible. Should refractory chrome ore become more expensive, the trend to increased usage of magnesite will be accelerated.

The demand for chrome ore for refractories manufacture is projected to increase through expansion of crude steel production. At the assumed growth rates for crude steel production here and abroad, chrome ore consumption for refractory purposes in the Free World by 1970 could reach 1.3 million long tons. This increase would be about 1.4 times the estimated 1956 consumption level of 900,000 long tons.

If the average annual post-war growth rate for chrome chemicals of about 3 pct (base 1954-1955) is assumed to continue through 1970, chrome consumption for chemical use in the Free World is expected to reach 437,000 long tons or 1.2 times the estimated consumption of 361,000 long tons in 1956.

Reserves: The Transvaal and Southern Rhodesia account for an estimated 80 pct of the lode chrome reserves of the world. The Transvaal's reserves of chemical ore are measured in tens of millions of tons, and Southern Rhodesia's reserves of standard and marginal metallurgical ore and refractory ore are very extensive. Turkey also has large reserves. New Caledonia is currently an important source of high-grade metallurgical ore, but its reserves have not been fully defined. The Philippines is the principal U. S. source of refractory chrome ore, but reserves are being depleted faster than new deposits are being found. The Philippines also have some reserves of metallurgical ore. Cuba is the second largest U. S. source of refractory ore, but its reserves are not extensive. Among the other Free World sources are India, Pakistan, Sierra Leone, and Greece.

In the Soviet sphere, the USSR is reported to have extensive deposits of chrome ore, and Albania's reserves are said to be substantial.

In addition to the commercial reserves and subgrade resources contained in the world deposits of lode chrome ore, large potential sources of chrome occur in chromiferous laterites in Cuba, the Philippines, Celebes, and the USSR. Cuban reserves of such material are estimated by the U. S. Bureau of Mines at 3 billion tons containing about 50 million tons of chromic oxide.

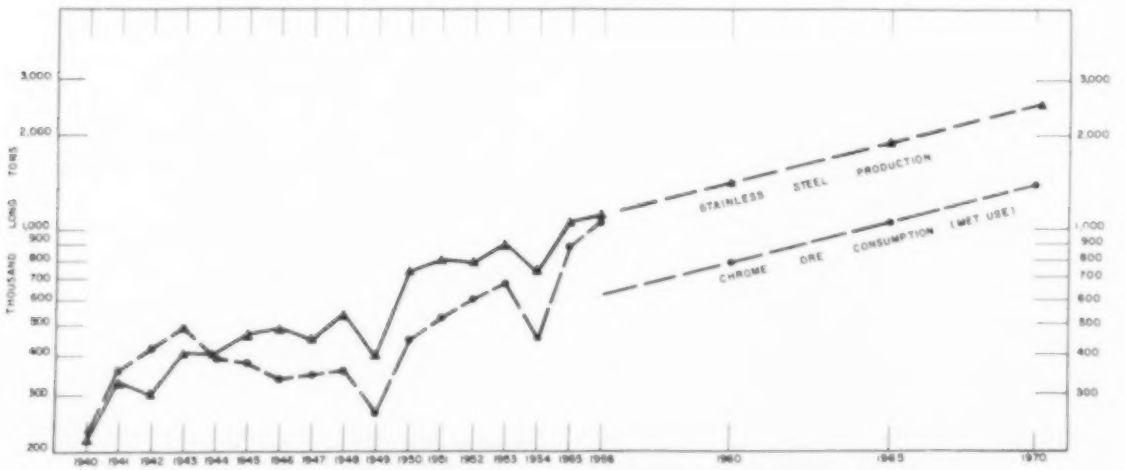
Free World Trade: With the exception of the USSR, chrome ore production is in underdeveloped areas, hence the bulk of the world's output enters international trade channels.

As in the case of manganese, transportation is a key factor, and inadequate transportation facilities in the Free World producing countries has hindered deliveries in the past. Because of the distances involved, ocean freight makes up a substantial part of the cost of the ore in Free World countries.

Supply: Chrome ore production in the Free World in 1957 amounted to about 3.5 million tons and was mainly in four countries: Turkey, Southern Rhodesia, Philippines, and Union of South Africa.

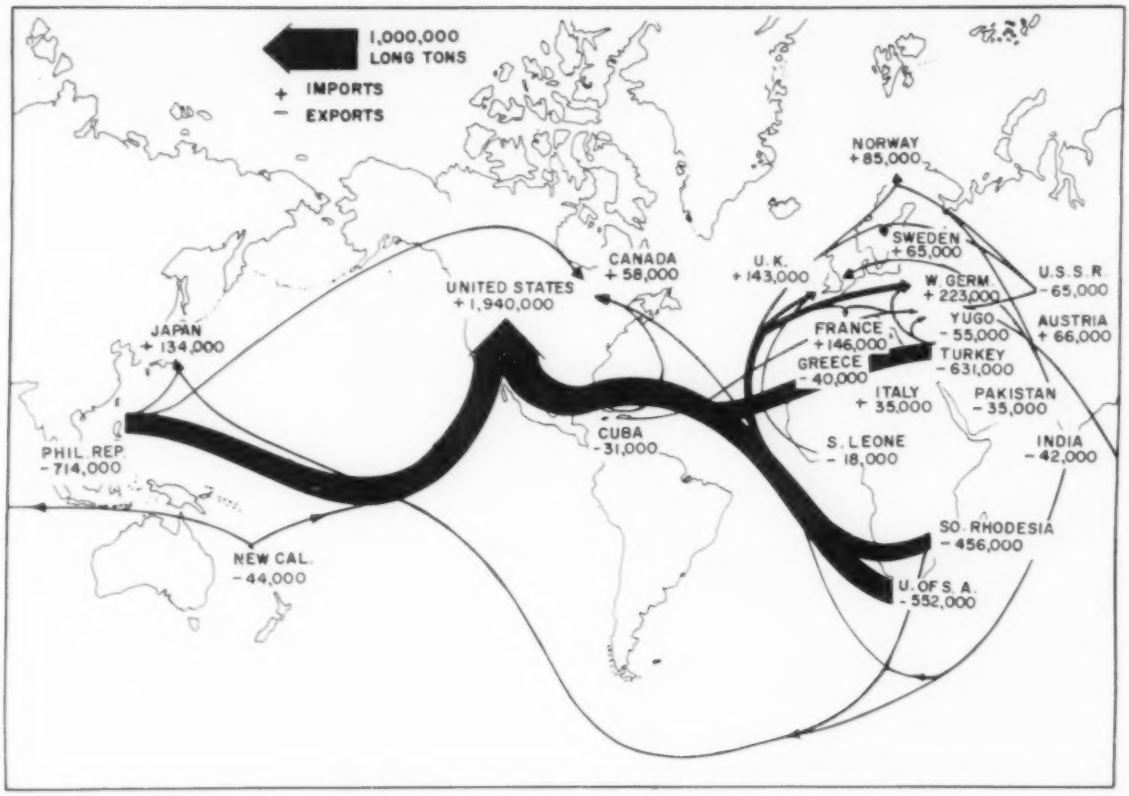
It has been estimated* that world reserves of lode deposits by type are roughly as follows: high-grade metallurgical lump, 15 to 20 pct; high-alumina refractory 2 to 3 pct; and high iron chemical, 75 to 80 pct. In contrast, the use pattern over the last

* Personal communication, T. Thayer, U. S. Geological Survey.



United States Chrome Ore Consumption for Metallurgical Use and Stainless Steel Production 1940-1956 with Projections at 6 pct through 1970

NOTE: Chrome ore consumption projected from the average of 1953 and 1954, as later years reflect Government stockpiling of ferrochrome. SOURCES: AMM "Metal Statistics"; AISI; USBM Mineral Yearbooks and 1955 Preprint, Mineral Industry Surveys.



World Trade in Chrome Ore 1956, Long Tons

SOURCES: Statistical Summary of the Mineral Industry 1951-56; USBM Mineral Industry Surveys; U.S. Department of Commerce.

decade has been roughly 50 pct high-grade metallurgical lump; 35 pct refractory and 15 pct chemical.

If Free World demands increase as projected, supplies of high-grade lump ore presently required for metallurgical use and high-alumina ore preferred in the U. S. for refractories manufacture, are expected to become progressively short. This will require significant changes in metallurgical technology to permit the increased use of friable ores and ores of lower grade to meet these demands. It is anticipated that principal Free World sources of chrome ore through 1970 will continue to be about as they have been in the past with a significant shift to Southern Rhodesia and the Transvaal for refractory ore as Philippine and Cuban reserves become depleted.

U. S. Position: Practically all of the chrome ore consumed in the U. S. is imported. In 1957, chrome ore imports amounted to 1.8 million long tons, of which 25 pct came from the Union of South Africa, 25 pct from the Philippines, 24 pct from Southern Rhodesia, and 18 pct from Turkey. The remaining 8 pct was supplied from six other countries.

Known U. S. reserves of chromite occur in California, Montana, Oregon, and Alaska. Some of the chrome ores in California, Oregon, and Alaska are technically acceptable but cannot be mined at current competitive prices. Extensive deposits of low-grade reserves of ore not acceptable in present practice occur in Montana and Oregon.

Production (shipments) in 1957 amounted to 147,000 long tons. All output was from California, Montana, Oregon, and Alaska. About three-fourths of the production was submetallurgical-grade concentrate derived from ores of the Mouat Mine in Montana, which is operated by the American Chrome Co. with the aid of a loan and purchase contract by the Government.

Virtually all the domestic output was purchased by the Government at incentive prices under the Purchase Program for domestic ores and concentrates and under the terms of a contract with American Chrome Co.

Large scale exploitation of U. S. reserves awaits the development of economic methods for utilization of low-grade ores.

Position of the USSR: The chrome resources of the USSR are known to be extensive. Output in 1956 was estimated at 600,000 long tons, the bulk of which was used within the Soviet Union, or went to Soviet bloc countries or Soviet stockpiles. About 65,000 tons was exported to the United Kingdom, Germany, Norway, and Sweden.

Formerly a principal Free World source of metallurgical ore, the USSR is again entering the world market. It is believed that in the foreseeable future the USSR will continue to export in the range of 70,000 to 100,000 tons. It is also to be expected that exports from Albania to the Free World will expand for foreign exchange.

MATERIALS SCIENCE AND MATERIALS ENGINEERING

When materials are viewed from the vantage point of how they are processed and used rather than from the science that underlies and explains their behavior, it is difficult to differentiate problems associated with different classes of materials; hence, the trend toward materials scientists and engineers.

by John H. Hollomon

UNTIL the middle 19th century, there was little science or engineering of metals. Metallurgy was lore handed from father to son, from master to apprentice and was closely guarded like witchcraft. But in the early 17th century, chemistry, born out of metallurgy by curiosity, began to influence the development of both the metallurgical industry and metallurgy. This chemistry of metallurgical processing was the origin of metallurgical engineering in the 19th century. The development of the open-hearth process for steelmaking was a triumph of the application of inorganic chemistry to metallurgical processes. The Hall aluminum production process, invented in the early part of this century, was a triumph of electrochemistry, a branch of the developing chemistry and of the technology of electrical engineering. The Kroll process for the production of titanium is another application of inorganic chemistry to the refining of a metal. The interaction of chemistry with the practical production of metallic materials led to chemical engineering and is responsible for its kinship to metallurgy. Even now in many academic institutions in America, metallurgy is still associated with chemical engineering and is considered to be based only upon chemical process technology.

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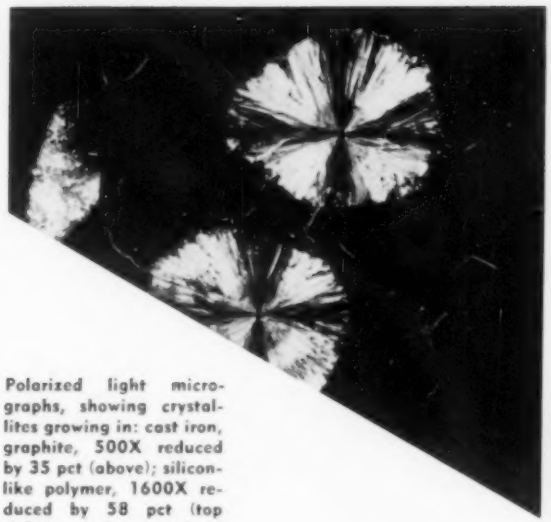
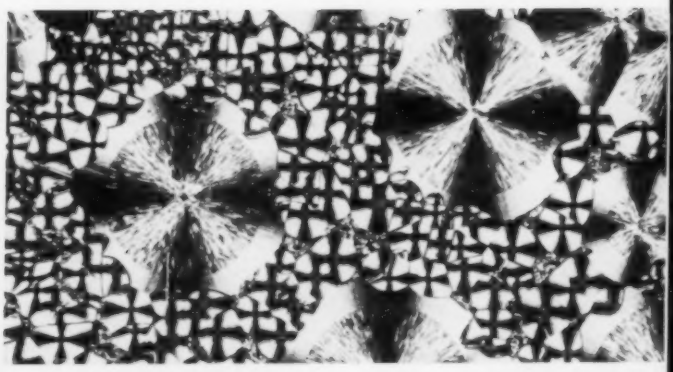
Examining the structure of metals

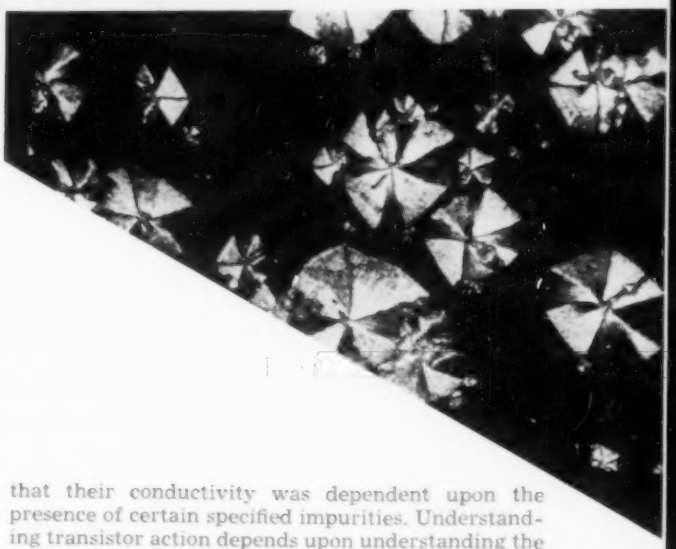
Near the turn of the century, metallurgists began to use the microscope to examine metals. They observed microstructures and correlated them with the differences in the behavior of metals and alloys, particularly their mechanical behavior. Almost simultaneously, thermodynamics began to be used by scientists, such as Rooseboom and Tammann, to understand the origins of the structures of metal samples. Bain and Mehl in America, and the metallurgists at the Kaiser-Wilhelm Institute for Eisenforschung in Germany applied the knowledge of the kinetics of reactions of Volmer, Becker, et al., to the nucleation and growth of phases that were revealed by microscopic examination. X-ray diffraction began to be applied to the identification of structure and to the description of the crystallography of the deformation process.

Metallurgy, prior to about 1935 to 1940, was dependent almost exclusively on inorganic chemistry, on thermodynamics, and to a much lesser extent, on the understanding of basic principles of kinetics, that is, of nucleation and growth. Metallography depended on optical and X-ray techniques. About this

Information on the role of dislocations in plasticity of solids has been gained by studying ceramics, metals, and semiconductors. Examples of etch-pit technique for revealing location of dislocations: lithium fluoride at left; and silicon iron at right.







Polarized light micrographs, showing crystallites growing in: cast iron, graphite, 500X reduced by 35 pct (above); silicon-like polymer, 1600X reduced by 58 pct (top right); and amorphous tantalum oxide, 500X reduced by 33 pct (bottom right).

time it became clearly recognized that the significant engineering properties of metals depended uniquely on their structures, both the obvious and those difficult to see.

And ceramics

The study of ceramics progressed along a parallel course, the analogous events occurring perhaps 20 years later. Beginning about 1920, or perhaps a little earlier, inorganic chemistry began to be applied to the processing of the oxides and the silicates that make up porcelains and clays. In the US, the University of Illinois was the leader in the development of a ceramic technology based on inorganic chemistry and on thermodynamics. It was not generally recognized until very recently, however, that microstructure affected the properties of ceramic materials even though petrographic and X-ray techniques had long been used for phase identification.

Organic to polymer chemistry

The development and use of plastics and polymeric materials came with the development of organic chemistry over 100 years ago. As soon as it was determined that the carbon-hydrogen bond had peculiar characteristics and could be manipulated to produce new organic compounds, and oil and coal derivatives could be made to produce new kinds and types of materials, polymer chemistry evolved. From these beginnings, polymer chemistry and the associated technology permitted the growth of the modern chemical industry based on chemical synthesis. It is on this ancient technology that this industry depends. The importance of the microstructure of polymers was recognized only within the last several years.

Electron bonding explained

Semiconductors, used for years in radio crystal sets, began to be industrially important with the development of the transistor. Quantum mechanics had made possible an understanding of the bonding of electrons and had answered questions about the transport of electrons in solids, explaining the difference between the conductivity of metals, insulators, and semiconductors. It was apparent that semiconductors were distinctly different from metals, and that their conductivity was dependent upon the presence of certain specified impurities. Understanding transistor action depends upon understanding the quantum mechanical properties of electrons and the intimate electronic-atomistic interactions. The development of solid state electronics depends upon this knowledge and upon the application of established metallurgical techniques to semiconductor materials through the production of single crystals of pure materials.

It is now becoming clear that the cohesion of all these solids is determined by similar considerations; binding is determined by the complex interaction of ions and electrons. Only through an understanding of this interaction can the binding between the atoms be predicted. Furthermore, it has become recognized that the mobility of atoms or molecules during diffusion in the solid state is governed by the same set of rules. The deformation behavior of all crystalline materials, whether oxides, carbides, borides, or metals is determined by the generation and motion of defects (dislocations). The most beautiful example of a dislocation actually observed in the process of deforming of a crystalline solid was obtained in studying the infrared transmission in semiconducting silicon. More recently, dislocations have been observed in lithium fluoride and by different techniques similar dislocations have been found in silicon iron, an important commercial metallic magnetic material.

The science that underlies the behavior of metals, ceramics, semiconductors, or polymers is the same and it can be applied even when the materials are not crystalline. One of the most important problems that faces the physicist and chemist today is the understanding of the detailed nature of the liquid state

and how the properties of liquids can be predicted from a prior consideration, and how these same properties differ from the properties of the corresponding crystalline solid.

Materials viewed from processing standpoint

When materials are viewed from a different vantage point: that of how they are processed and used, rather than from that of the science that underlies and explains their behavior, it is equally difficult to differentiate problems associated with different classes of materials.

Certainly, the process technology that is involved in calendaring (rolling, to you metallurgists) of plastics is the same as that involved in rolling metals. The process of uranium purification is based on the same principles of inorganic chemistry as in that of germanium. Melting and casting of ice is actually a foundry process.

The aircraft designer, like the designer of turbines, in company with the automobile designer, joins the designer of refrigerators in asking, "what is the best material," how it is specified, and how it is to be developed. He is not concerned with whether or not the material is metallic, ceramic or made of green cheese.

The engineer interested in the development of power plants is concerned with the improvement of materials that are used in the turbine blade, and he wants the best material.

The engineer or architect who designs a modern building is more concerned with the character of the material which he utilizes, its properties, and its relative economy in a particular application, than he is with whether the material is metallic or ceramic. The electronics engineer devising an I-F circuit questions whether he should use powdered iron or a piece of lodestone (called ferrites in their modern guise). He is not concerned with the question of whether the material he is going to apply is metallic or non-metallic. But he is concerned with the properties of all materials at high frequencies.

Material engineers

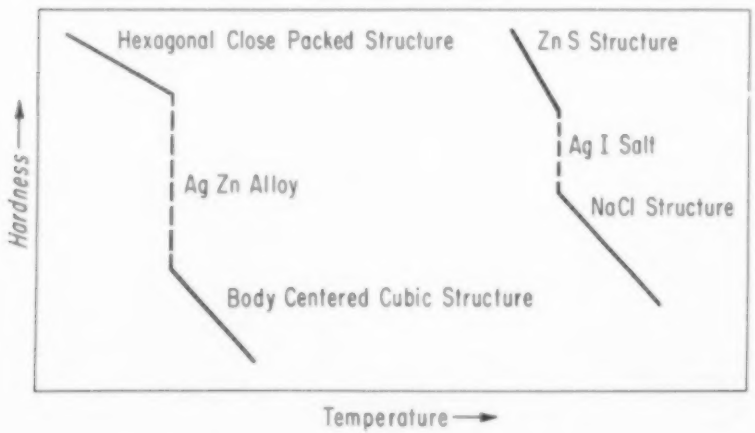
In the materials-consuming industries, electrical and mechanical engineers are often converted to materials engineers because ceramists, metallurgists, polymer chemists, and semiconducting physicists are often too specialized in their outlook. In these industries, far more people study, develop, and apply metals than produce them in the metals-producing industries. These people determine the requirements to be met by materials in the expected service. They specify the properties of the materials, assist in their choice for particular use. They develop materials—they are material engineers, not metallurgical engineers.

In industry and in government, there is a great need for materials engineers, for those who are versed in the problems that have to do with the specifications of materials, the technology and science involved in their development, their processing, and the factors that control their properties.

The curriculum of universities and institutes of technology and colleges will change to recognize that the behavior of all materials is determined by the same rules and that these rules are described by thermodynamics, by statistical mechanics and kinetics, and by the physics applied to solids. Several of our leading institutions are taking the first tentative steps toward this new approach. The curriculum that produces a materials scientist is broadly applicable to all materials and should not be a narrow application of science to metals or ceramics, semiconductors, or polymers. The provincial view of many metallurgy departments has led to the offering of materials courses and materials research in almost all the other academic engineering departments from the *mechanics of materials* in mechanical engineering to *molecular engineering* in electronics. Physics departments treat solid state science separately, and the technology of polymers is taught in the chemistry departments. The broader, more catholic view will include these activities to the mutual benefit of all.

Since science is equally applicable to all materials, research and development laboratories that permit the broad application of science to all classes of materials must be established. Organizations restricted to particular materials cannot attract the broadly interested scientist or allow the full exploitation of the consequential science. On the other hand, the interaction of physicists, chemists, metallurgists, and ceramists applying their developments to all materials will be extremely fruitful.

The professional societies must recognize this new alignment and arrange for its stimulation and for the association of those who practice both the science and engineering of materials. We might even need an American Materials Society with divisions of science and engineering. Metallurgical engineering will become materials engineering. Out of metallurgy, by physics, comes *materials science*.



Transformation characteristics of a silver-zinc alloy and a silver-iodide ceramic are similar.

COLUMBIUM-TREATED STEELS

low-cost, high-strength

Efforts to produce high-strength, mild-carbon steels have led to the investigation of additives required for the formation of fine grain structure. Vanadium has been used for several years. Now columbium-treated steels have hit the market as a new low-cost answer.

by F. Weston Starratt

First to hit the market with columbium-treated steels is Great Lakes Steel Corp. with the announcement of its new GLX-W series. This is not the first, nor the last, that we shall hear of these steels, but Great Lakes, in an effort to diversify production and reduce dependence upon the cold-rolled sheet market, has been pushing hard and fast in this realm of low-cost, high-strength, mild-carbon steels. The object of this effort is the development of a new market for medium and light plate. Columbium-treated steel, in the form of hot-rolled plate, is expected to find such a market with the producers of welded linepipe and light structural shapes.

Largely economics

While the properties of the new columbium-treated steels may be achieved by other alloying elements, the basic factor in their present development is largely one of economics. Vanadium-treated steels, brought out several years ago by major steel producers, were also fine-grained, mild-carbon steels that could achieve many of the physical requirements of alloy steels, but at greatly reduced costs, due to the small quantities of vanadium required. Columbium now shows signs of achieving the same physical requirements at even lower costs. Ferrocolumbium itself is not excessively expensive, and additions probably on the order of 0.01 to 0.03 pct Cb so change the solidification mechanism of mild-carbon steels as to produce a fine-grained structure, characteristic of tough, high-strength steels, previously produced by costly heat treatment or alloy additions. In the mild carbon ranges of semi-killed steels, the addition of columbium can raise the yield strength as much as 20,000 psi and tensile strength by about 15,000 psi.

The new GLX-W steels, with carbon from about 0.14 to 0.20 pct and manganese at 0.40 to 1.00 pct are being produced in yield strengths up to 60,000 psi in hot-rolled plate at prices from 10 to 20 pct above those of carbon plate and considerably below the prices of alloy plate. Because of high strength, efficient design can result in a considerable reduction in the weight of columbium-treated steel required for a given structure or in the thickness of plate demanded by a pressure vessel or line pipe. The possibility of such weight reduction means a considerable savings when the columbium treated steel is substituted either for carbon or for alloy steel plate.

Little has been said of the cold working properties of columbium-treated steels, and Great Lakes is offering it only in the form of hot-rolled plate, with its hopes largely pinned on the producers of line pipe. Columbium treated steel's high-strength, ductility, and weldability commend it particularly for this use.

Other producers coming

Great Lakes Steel Corp. may have to consolidate its position rapidly, for other steel companies have also become interested in columbium-treated steels. Republic Steel Co., for one, is reported to have worked out production problems and will shortly put its brand of columbium-treated steels on the market. The idea itself has largely been that of the Molybdenum Corp., who, seeing the success of vanadium-treated steels, has felt that columbium might do an equal or better job.

An important step

This new development of columbium-treated steels, following that of the vanadium-treated family, and perhaps even a forerunner of other fine-grained steels is, according to the best estimate from industry, an important step forward in the production of low-cost, high-strength metal by the steel industry.

W. D. MacDonnell, president of Great Lakes Steel Corp. has stated that cost savings effected by the new columbium-treated steels range up to 35 pct. "The new steels are regarded as an important metallurgical advance, because they make available, on a volume production basis, superior qualities of strength, toughness, and weldability, previously obtainable only in higher priced steels and the even more costly light metals used in many products."

NICKEL-COBALT SEPARATION AT SHERRITT GORDON

Treating a complex nickel-copper-cobalt sulfide concentrate in a leaching operation has required the development of special techniques for the separation of nickel and cobalt. The process described in this paper can be applied with only minor modifications to a wide range of nickel and cobalt bearing solutions.

Summarized from an article by

V. N. Mackiw, W. C. Lin, R. L. Benoit, and T. W. Benz

THE Sherritt Gordon nickel refinery at Ft. Saskatchewan treats nickel-copper-cobalt sulfide concentrate in a continuous leaching operation, using ammonia and compressed air at 180°F and 100 psig pressure. Nickel, cobalt, and copper are dissolved in the form of complex metal ammines. Iron remains with the undissolved solids mainly as ferric oxide and is separated from solution by thickening and filtration. Copper, precipitated from solution as the sulfide, and excess free ammonia are removed in a continuous distillation and filtration operation. A stripping step, using hydrogen sulfide or elemental sulfur, removes the residual copper, producing a copper-free solution.

This solution is purified in a combined oxidation and hydrolysis operation, where the unsaturated sulfur compounds are oxidized and ammonium sulfamate is hydrolyzed. The purified solution, containing 45 g of Ni per liter and 0.8 g of Co per liter, is then subjected to a batchwise reduction operation, using hydrogen as the reducing agent and ferrous sulfate as a catalyst. Nickel is reduced selectively and precipitated as a metal powder. The reduction is continued until the nickel concentration in solution decreases to approximately 0.8 g per liter. At this point only about 8 pct of the cobalt present in solution has been reduced. Thus, the first step in the separation of nickel and cobalt is achieved during the routine reduction operation in the nickel refinery.

After nickel reduction, the solution contains about 0.8 g per liter each of nickel and cobalt. These metals are precipitated from solution with hydrogen sulfide and the resultant mixed sulfide residue separated from solution by filtration. The barren solution, containing ammonium sulfate, is sent to the crystallizer for the production of fertilizer-grade ammonium sulfate. The mixed nickel-cobalt sulfide precipitate is then pressure leached and the clarified leach solution subjected to a two-step hydrogen reduction in order to recover nickel and cobalt separately.

V. N. MACKIW, W. C. LIN, R. L. BENOIT, and T. W. BENZ are with the Sherritt Gordon Mines, Ltd., Ft. Saskatchewan, Alberta, Canada. This paper was presented at the 1958 AIME Annual Meeting.

Process description

Development work on the cobalt recovery process was started in the Research & Development Div. of Sherritt Gordon Mines as early as 1952. By the end of 1954, enough data had been accumulated to allow preliminary pilot plant operations to be started. The process was finalized early in 1955, and immediately thereafter the production of specification cobalt powder was undertaken on a semi-commercial scale.

The process consists of the following operations:

a) Preparation of sulfide slurry for leaching;
b) Dissolution of nickel and cobalt as sulfates by oxidation in aqueous acid solution at an elevated temperature and pressure;
c) Removal of iron from the leach solution by precipitation and filtration;
d) Preferential reduction of nickel by hydrogen at an elevated temperature and pressure;
e) Reduction of cobalt by hydrogen, also at an elevated temperature and pressure; and
f) Handling of metal powder (washing, drying, briquetting).

a) Feed slurry preparation

The mixed nickel-cobalt sulfides precipitated in the refinery are filtered and washed with water in a Sweetland filter press. After washing, the material has the following typical analysis on a dry basis: 19.9 pct Ni, 19.7 pct Co, 0.2 pct Fe, 31.0 S_t, 9.5 pct NH_3, and 1.3 pct Zn. The calculated ammonium sulfate content is 36 pct.

The mixed sulfide filter cake is repulped with water in an agitated tank. The amount of repulp water is controlled so that the required concentration of metals will be reached after leaching. The slurry pH is then adjusted with sulfuric acid to ensure proper conditions during leaching. Finally the feed slurry is pumped continuously into the leaching autoclave.

b) Leaching

The dissolution of mixed nickel-cobalt sulfides into solution as sulfates was found practical in an acid medium at an elevated temperature when using compressed air. A number of variables—pH, temperature, pressure, ammonium sulfate concentration, quantity of air, and agitation—affecting the above reactions were studied in detail to establish the optimum operating conditions.

It was found that unless the pH of the solution during leaching is sufficiently low, ranging from 1.5 to 2.5, oxidation of the sulfide sulfur is incomplete and such unsaturated sulfur compounds as $SO_3^{=}$, $S_2O_3^{=}$, and S_xO_6 are formed. If present in excessive amounts, these compounds are not oxidized completely during the subsequent purification step, and cause a high sulfur content in the final metal product. Furthermore, basic salts of nickel and cobalt tend to precipitate at higher pH and so increase the losses of these metals in the iron oxide residue. Hence, the mixed sulfides slurry is adjusted with sulfuric acid prior to leaching.

Generally, higher temperature promotes faster reaction rates, but the corrosion of the vessel under acidic conditions must be considered. Since air passing through the solution will carry with it more water vapor at higher temperatures, heat loss due to evaporation becomes excessive as the temperature is increased. Considering all the problems involved, a temperature of 250°F and a total pressure of 100 psig were selected as optimum conditions.

Leaching is carried out in a stainless steel, horizontal, multi-compartment autoclave. Each compartment is equipped with an agitator and a stainless steel coil. Either steam or cooling water may be used in the coil to maintain the required process temperature.

Air is injected into each compartment directly under the agitator. An excess of air is necessary to achieve fast reaction rates. However, increasing the air supply to give an oxygen utilization below 50 pct does not improve the reaction rate further. Thus, feed rate is controlled closely to achieve a 50 to 60 pct oxygen utilization.

The concentration of ammonium sulfate in the leach solution in the range of 0 to 150 g per liter was studied. Over this range, it was found that the concentration has little effect on leaching. However, a minimum of 80 g per liter is necessary to prevent the precipitation of basic metal salts in the subsequent reduction operation. At concentrations above 100 g per liter, crystallization of the salts from solution is encountered, making it difficult to handle the solution. In addition, it was found that at high concentrations the rate of reduction is slowed down considerably in the subsequent nickel preferential reduction step. Hence, the concentration of ammonium sulfate is set at 80 to 100 g per liter in the leach solution.

The retention time in the autoclave is approximately 2 hr. After this time, more than 95 pct of the nickel and cobalt are oxidized to form soluble sulfates. The pH of the discharge solution ranges from 1.5 to 2.5 and the metal (Ni + Co) content averages 50 to 60 g per liter. The discharge solution contains ferrous and ferric sulfates, as well as fine suspension of unleached nickel and cobalt sulfides and ferric oxide particles; all of these impurities have to be removed to ensure the purity of the final metal product. This is done in the next operation—solution purification.

c) Solution purification

The purpose of the purification step is to remove from the solution all of the compounds that may eventually affect the purity of the final metal product. These are the soluble ferrous salts and fine suspension of unleached sulfides.

The autoclave discharge solution is cooled to 180°F and transferred to an agitated tank where purification is effected at atmospheric pressure. Air is supplied to oxidize the ferrous salts, and the pH is raised to approximately 5.0 to precipitate all the iron in the form of hydrated ferric oxide. The pH is adjusted by the addition of anhydrous ammonia.

Of the other process variables operating pressure, temperature, and agitation were studied. The results indicated that very little could be gained by the application of higher than atmospheric pressure. In addition, a temperature above 160°F helps to coagulate the ferric oxide precipitate which improves the filtration characteristics but does not increase appreciably the rates of oxidation and precipitation. Good agitation of the slurry was found to be essential, since it had an appreciable effect on the oxidation and precipitation rates. Thus, in practice, the purification reactions are carried out at atmospheric pressure in an agitated tank at 180°F with a solution pH ranging from 4.9 to 5.1.

Solid ammonium sulfate is then added to the purification vessel to increase the concentration to the level required for optimum performance in the nickel reduction operation. The solution from the purification step is clarified using a vacuum leaf filter and filter aid. The residue is recycled to the leaching circuit in the main refinery. The purified and clarified solution is now ready for nickel preferential reduction.

d) Nickel preferential reduction

Nickel preferential reduction effects the separation of nickel and cobalt from solutions containing soluble sulfates of both metals. Nickel is preferentially precipitated by reacting the solution with hydrogen under closely controlled conditions of pH, temperature, and pressure.

Like all other reduction operations at Sherritt Gordon, the nickel preferential reduction is performed in an agitated horizontal autoclave equipped with three agitators each having two Struthers Wells impellers. These are radial-type impellers with vertical blades. This process consists of a series of batch operations grouped in cycles. Such a cycle consists of the following operations:

1) Nucleation leach,
2) Nucleation reduction,
3) 12-15 densification reductions, and
4) Plating leach.

The purpose of the nucleation leach is the preparation of a solution suitable for the following nucleation reduction. It is done by leaching nickel powder with air in an ammoniacal ammonium sulfate solution. The leaching is carried out at 200°F under a 100 psig air pressure. The initial ammonium sulfate concentration is 200 g per liter. The desired final nickel concentration is 40 to 45 g per liter, and the nucleation leach operation takes normally 6 to 8 hr.

Nucleation reduction produces seed powder for use as a catalyst in the subsequent densification reductions. The autoclave is first purged with inert gas and then with hydrogen. The solution temperature is then raised to 350°F, the nucleation catalyst is injected into the autoclave, and hydrogen is introduced. During the nucleation reduction, the pressure is maintained at 500 psig. Using ferrous sulfate as a catalyst, the nucleation reduction is normally completed in a few minutes. The fine powder is allowed to settle, and the nucleation end solution is decanted from the powder.

Next the autoclave is charged with preheated purified leach solution, and again brought to the operating temperature of 350°F and pressurized with hydrogen to 500 psig. An antiplastering agent is injected into the autoclave and enough ammonia in aqueous form is supplied so that all the nickel in solution is reduced. In this case, the nickel particles present act as the catalyst. Freshly reduced nickel coats the seed particles in the suspension, increasing their size and apparent density, thus the term *densification* is applied to this step. The antiplastering agent is a solution of stearic acid, and it is added to prevent agglomeration of the metal particles and formation of *plaster* on the walls of the autoclave. After all the nickel is removed from the solution, the powder is allowed to settle, the cobalt-bearing solution is drawn off, and the autoclave charged again with a fresh batch of leach solution. An average nickel preferential reduction cycle consists of 12 to 15 densifications, averaging 60 min each. The reduction rate decreases gradually with the number of densifications, this is due to the increasing coarseness of the powder with a consequent gradual decrease of its activity as a catalyst.

After the last densification, both the solution and the powder are dicharged into the flash tank. The solution is decanted and joins the produced previously batches as the cobalt reduction feed solution. The metal powder produced contains up to 20 pct Co and is either recycled to the refinery leach circuit or is washed, dried, briquetted, and sold as a finished product.

The reduction autoclave is then purged again with inert gas in preparation for the plating leach. During the densifications, approximately 5 pct of the metal deposits in the form of a hard scale on the autoclave walls. This plating has to be removed after the completion of each cycle to ensure satisfactory nucleation in the following cycle. It is leached with ammonium sulfate solution and air at 200°F and 100 psig total pressure.

After the plating leach, the nickel preferential reduction circuit is again ready for the nucleation leach.

e) Cobalt reduction

Cobalt reduction is performed in equipment identical to that used for nickel preferential reduction. The sequence of operations and the operating conditions are similar with the following exceptions:

1) A small amount of a mixture of sodium sulfide and sodium cyanide is used as the catalyst for the nucleation;

2) Ammoniacal polyacrylic acid solution is used as the antiplastering agent during the densification operations;

3) An excess of ammonia is added to the autoclave to ensure the complete reduction of cobalt;

4) The number of densification operations performed per cycle is greater, ranging from 25 to 30; and

5) The plating leach is carried out using ammonium sulfate solution containing enough ammonia to give a free ammonia:cobalt ratio in the leach solution in excess of 5:1.

The plating leach solution cannot be used for nucleation; so, it is recycled to the cobalt-bearing solution in storage. The cobalt reduction end solution contains approximately 0.8 g per liter of residual cobalt and 250 g per liter of ammonium sulfate. It is transferred to the ammonium sulfate recovery plant.

The kinetics of both nickel and cobalt reduction is described in some detail in the original article.

f) Metal powder handling

Like the nickel powder, the cobalt powder can be washed efficiently using water and a pan filter. Care must be taken to prevent contacting cobalt powder with air, since it oxidizes rapidly, and in the drying operation an inert atmosphere has to be provided. At the Sherritt Gordon plant a vertical-type drier is used. Preheated nitrogen is used as the drying medium.

Dried cobalt powder is either briquetted or sold in its original form.

Commercial application of the process

As soon as the principle features of the new process were worked out by Sherritt Gordon research laboratories, pilot plant operation on a semi-commercial production scale was undertaken. A new pilot plant was designed and built at Fort Saskatchewan. The designed capacity of 500 lb of specification cobalt powder daily was reached after a few months of operation.

The typical compositions of the materials used and produced in the course of the operations were as follows:

		Ni	Co	Fe	S_t	NH_3
Mixed sulfides	pct	19.9	19.7	0.2	31.0	9.5
Purified leach solution	g/l	26.4	26.2	0.01	54.2	26.3
(NPR feed solution)						
NPR metal powder	pct	83.5	16.0	0.03	0.02	—
NPR discharge solution	g/l	0.10	23.1	0.02	59.6	41.1
Cobalt powder produced	pct	0.39	99.3	0.03	0.02	—
Cobalt reduction end solution	g/l	0.04	0.78	0.02	65.1	68.8

While important in treating solutions at the Sherritt Gordon plant, the importance of the new process lies in the fact that it can be applied with only minor modifications to a wide range of nickel and cobalt bearing solutions.

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NUCLEAR METALS OPENS NEW LABORATORY

Consistent with the constant demand for increased knowledge of the "exotic" metals, Nuclear Metals, Inc., has expanded research facilities by transferring operations to a new laboratory at Concord, Mass.

DEDICATION of a two million dollar research and development laboratory in Concord, Mass., marked the latest advance of Nuclear Metals Inc., in the field of metallurgy. It is situated on a 40 acre tract, a short distance from the Waldon Pond and the Emerson House. The 86,000 sq ft, functionally-designed building is equipped to carry out research and development programs in fundamental research, physical metallurgy, extractive metallurgy, fabrication, fuel element manufacturing, and high-temperature materials.

Nuclear Metals was formed in 1942 as the Metallurgical Project of the Massachusetts Institute of Technology and continued under MIT auspices until 1954, when Arthur D. Little, Inc. and Allegheny Ludlum Steel Corp. were selected by the US Atomic Energy Commission to continue the activities of the Metallurgical Project. In addition to serving as a prime contractor to the AEC in the research and development of new materials, Nuclear Metals has carried out extensive work for the US Dept. of Defense and private industry.

The original assignment given to the MIT group in 1942 was the development of uranium melting techniques for the first Chicago pile. Nuclear Metals' most recent assignments include the development and manufacture of fuel elements for the Enrico Fermi Fast Breeder Reactor and development of nose cone materials for re-enty into the earth's atmosphere. Between these assignments, it has worked on virtually every existing metal in the development of new materials for the nuclear-space age.

Nuclear Metals has carried out research and development work on the pure metal, alloys, and compounds of beryllium, aluminum, vanadium, chromium, gallium, yttrium, zirconium, columbium, molybdenum, hafnium, tantalum, tungsten, thorium, uranium, and a number of the rare earth metals.

Research groupings

Nuclear Metals' research and development efforts are grouped into departments operating under the supervision of Dr. Albert R. Kaufmann, vice president and technical director.

The Mechanical Metallurgy Dept. consists of an Engineering Metallurgy group, a Materials Fabrication group, a Foundry group, a machine shop, and a welding shop. The Engineering metallurgy group develops methods of forming metal and cermet materials into useful shapes by melting, working, shaping, and cladding one metal with another.

One of many spectacular developments at Nuclear Metals is a technique which permits the welding of most metals in vacuum. It makes use of a focussed stream of electrons shot from an electron gun.

The Metallurgical Research and Development Dept. consists of groups in chemical metallurgy, physical metallurgy, and fundamental research.

The Fundamental Metallurgy group studies such diverse phenomena as radiation damage, twinning mechanisms in zirconium, tandem and coextrusion fundamentals of materials, fracture modes in beryllium single crystals, and refractory metal phase diagrams.

The Physical Metallurgy group is concerned with the physical and mechanical properties of metals and alloys. It studies the properties of materials as well as ways of altering these properties. Typical functions are phase diagram determinations, heat treatment and annealing studies, diffusion investigations, the study of microstructure and macrostructure, and the determination of mechanical properties such as hardness, tensile strength, stress-rupture, and creep.

The Chemical Metallurgy group deals with the composition of metals, ceramics and cermets. Typical problems are purity, beneficiation additions, corrosion, electroplating, diffusion, reactor fuel cycles, spent fuel reprocessing, liquid metal solubility studies, and radiochemistry investigations.

The Concord laboratory has been specially designed and equipped to deal with the problems of this nuclear age. Research and development of the so-called "exotic" metals are playing an increasingly important role in today's world. Nuclear Metals' new facilities indicate the attitude being taken throughout the country to develop means of improving knowledge in this field.

DIRECT IRON ORE REDUCTION

Why are we reversing previous conclusions as to the impracticability of direct reduction? The answers appear to be largely economic: rising scrap costs and the high cost of new capital equipment. Another factor stems from the increasing availability of lower grade ores and the necessity for treating fines; this means higher capital and operating costs associated with the classical blast furnace.

Based on an article by

P. E. Cavanagh

IN the past few years there has been a revival of interest in the production of sponge iron for steel melting stock. There are at present a number of direct reduction processes under intensive investigation and four commercially operating proven processes for which production data are available. These processes offer a wide choice of method, and each is particularly suited to a definite set of conditions.

Commercial processes

These complementary methods are each producing in the neighborhood of 100,000 tons of metallic iron per year. We shall herewith review each of them.

1. Tunnel Kiln or Hogonas process

Small lumps of rich iron ore, sinter, pellets, or fine ore are charged into a sealed sagger along with a mixture of coke and limestone. The saggers, loaded on cars, are passed through a tunnel kiln and heated to about 2100°F, held for 12 to 36 hr, cooled, and emptied. This is the simplest and crudest of the direct reduction processes. Its great advantage lies in the reliability with which it will produce sponge iron from any iron ore. This is partly due to the fact that the ore is not moved during reduction. The main disadvantage is in the cost of the saggers, which may be metallic or ceramic. Metallic saggers can be used only at low temperatures of about 1900° to 2000°F which requires an easily-reduced rich ore and results in a low-temperature sponge iron, which may be pyrophoric in some cases.

P. E. CAVANAGH is vice president, Premium Iron Ores Ltd., Montreal; formerly director of metallurgy, Ontario Research Foundation, Toronto, Ontario, Canada.

Ceramic saggers may be used up to about 2250° to 2300°F, but they must be specially made for this service to survive iron oxide attack, the action of the reducing and furnace gases, and thermal shock.

In the most modern plan of this type at Oxelosund, Sweden, with two furnaces each producing 50 tons per day of sponge iron, loading and unloading are fully mechanized so that the ceramic saggers do not have to be moved from the kiln cars. This is a major advance in this process and results in a very simple method for producing melting stock sponge iron.

2. Wiberg-Soderfors furnace

In this process rich lump ore, pellets, or sinter are fed into the top of the furnace pre-heated to reduction temperature by combustion of a portion of the spent reducing gas, reduced to FeO by the same portion of the gas before combustion, and then reduced to metallic iron by the hot, rising, rich reducing gas.

Recycling of about three-quarters of the reducing gas withdrawn from a point part way up the shaft, gives a technically excellent way of achieving what is probably the lowest fuel consumption which can be attained in practice in a direct reduction process. Reducing gas enters the furnace at about 2000°F and is preferably composed of carbon monoxide and hydrogen in a ratio of 3 to 1. This is a continuous counter current process probably limited in unit size to about 100 tons per day of metallic iron.

Ontario Research Foundation regards this process as the best technical development to date in this field and regards the energy consumption of about 7.5 million Btu per ton of iron as the yardstick against which to measure the fuel economy of other suggested processes.

3. Mexican Process at Hojalata y Lamina

In this process, rich lump iron ore, sinter, or pellets are charged into a reaction vessel about the size and shape of a steel ladle. Hot gases are blown through the ore bed to heat it to reaction temperature of about 2000°F. Reformed natural gas is then blown through the bed of hot ore to reduce it to metallic iron. The ore does not move during reduction. When the desired degree of reduction is achieved, the whole vessel is picked up and transported to the electric steel furnace where the sponge iron, while still hot, is dumped in through the roof. This is a very simple process and can almost be regarded as an enlarged Tunnel Kiln Sagger where the reducing gas is supplied from an outside source rather than being generated inside the sagger. This is a batch process with a treatment time to coincide with the requirements of the electric steel-making furnace. Charging of hot sponge iron directly to the steel furnace is a major advantage.

Ontario Research Foundation regards this method as excellent for supplying hot melting-stock directly to steel furnaces within the same plant.

4. Rotary Kiln Methods

Small lump ore, sinter, pellets, or fine ore can be charged into a rotary kiln along with coal or coke and some limestone for desulfurization if necessary. The kiln is usually heated by a flame at the discharge end, as is the case with the kilns which have been in operation for many years at the National Radiator Co. in Johnstown, Pa., for making sponge iron for iron powder production, and at The Anaconda Co. for making sponge iron for copper cementation. Kalling, in Sweden, has also done extensive investigation into this type of process.

One useful modification is a concurrent kiln fired at the feed end. The advantages of concurrent operation of a rotary kiln are due to the facts that the ore is heated rapidly in an oxidizing zone, which eliminates sulfur and minimizes sticking, and that the reduced metal is discharged under reducing gas with easy temperature control.

The R-N process—described in the July 1958 issue of JOURNAL OF METALS—is now in the initial stages of commercial production; it represents a low-temperature type of operation where the sponge and gangue are discharged in the solid state without melting. The operation will obviously be more attractive on rich ores. However, in the case of medium grade ores, the reduced sponge iron can be magnetically separated after reduction to bring down the silica content of the resulting metallic melting stock before compacting. The same concentrating and compacting treatment can be applied to any sponge iron produced by any of the above methods.

Low-grade ores can also be treated with the rotary kiln, but output will naturally be cut down. One of the main troubles with rotary kiln processes is the difficulty of preventing sticking and balling of the charge in the kiln when any considerable proportion of unsuitable gangue is present. The sticking and balling tendencies of partially- or fully-reduced iron ore, added to the sticking tendencies of gangue minerals, make it necessary to run pilot operations on an ore before it can be stated definitely that operating difficulties will be within reason.

The Krupp-Renn process represents a special development of this type of equipment. If a very low-grade, highly silicious ore must be used, it is possible to consider the use of the Krupp-Renn process where reduction is carried out at sufficiently high temperatures so that the metal is fluid and the slag is semi-fluid. When operated on a low-grade ore, the output is naturally low per dollar invested, and the product is generally high in sulfur and more suited to a blast furnace feed than to melting-stock.

Capacity of equipment

As a second principle, Ontario Research Foundation believes that the end use of the product should have some bearing on the nature of the process and the unit capacity of the equipment. When some or all of the product is to be shipped to other users, a continuous process has advantages. Even here, the criterion of unit capacity is income per dollar invested and not unit size. We see no objection to the unit size of the Wiberg-Soderfors process, for example, for the same reasons that there are very few objections to the capacity and size of a unit coke oven.

Capital investment

In North America, the cost for a plant to produce large tonnages of metallic iron by any of these processes, or by any of the processes under development in North America, is in our opinion about $65 per ton year of capacity, which is about the same as the plant cost for a 1,000 ton-per-day blast furnace without the complete coke oven plant. This plant investment is the cost of a new plant with all handling and service facilities on a new site.

Possible exceptions in some locations are the capital cost of an unmechanized tunnel kiln installation using rich, fine concentrate, the cost of the Mexican process on rich pellets or lump ore, and the cost of an R-N installation to operate on rich concentrations. In these cases we estimate plant cost at about $45 per ton year.

Under present conditions in North America, a 1,000 ton-per-day blast furnace is nearly the smallest that can be operated competitively, at present steel prices and construction costs. The attractiveness of direct reduction processes from the investment point of view, therefore, lies mainly in the opportunity for producing iron profitably on a smaller scale and for a smaller total investment than that necessary for a blast furnace.

Performance

The tunnel kiln and Wiberg-Soderfors processes are adequately described in the literature. At the 1958 AIME Annual Meeting, the first descriptions of performance of the **R-N** plant of Republic Steel and National Lead in Alabama demonstrated the usefulness of this process on certain types of low-grade ores and on high-grade concentrates.

When operating on fine high-grade concentrate containing 69.5 pct Fe from Republic mines at Port Henry, N. Y., it was reported that energy consumption per net ton of metallic briquets produced was about 0.535 tons of reducing coke and about 9000 cu ft of natural gas kiln fuel with auxiliary electric power at 316 kw-hr. Total energy requirement was stated to be about 17,000,000 Btu per ton of iron produced.

It is interesting to note that phosphorus and sulfur removal in the R-N process have been shown to be very effective—in the neighborhood of 90 pct. In the kiln or sagger processes, where removal of these

elements can only be means of the gas phase, there is no significant removal of phosphorus and about 60 pct removal of sulfur with the same types of ores under the same conditions. There seems little doubt that the important advantage of the R-N method in this respect is due to solid contact in the moving bed as suggested. It is also interesting to note that going to a fluid metal at higher temperature in the Krupp-Renn kiln results in relatively poor sulfur elimination.

The R-N kiln, by introducing air at many points along the length, maintains a remarkably uniform temperature over a length of more than 66 ft. Sticking, balling of the charge, and lining refractory consumption have, therefore, been eliminated as major problems on suitable ore.

The 200 ton-per-day plant at **Hojalata y Lamina** in Monterrey, Mexico, is now in full operation after three years of pilot operation. It has five reactors, each holding about 15 tons of ore, which averages 66 pct Fe and range in size from 0.25 to 1.5 in. The reaction cycle requires 4 hr with an additional 30 min for dumping and charging. Reducing gas is provided from a Kellogg-designed plant by steam reforming natural gas which is inexpensive in this vicinity. Twenty-five thousand cubic feet of natural gas are used per ton of iron produced.

Final ore reduction takes place within a temperature range of 1600° to 1900°F. Metallic yield from the electric steel furnace charge has been increased 94 pct, and repairs and maintenance on the furnace shell are not excessive.

This plant represents a major advance in direct reduction techniques not only in the reduction process but also in the method of utilization of sponge iron. Hot sponge is used as at least 50 pct of the charge, and all of the steel made is rimming grade. Steel quality is excellent, and processing difficulties in the plant have been greatly reduced.

Plans to built a 175,000 ton per year plant at Monterrey, Mexico, have recently been announced. This new plant will be engineered and constructed by the M. W. Kellogg Co. and will provide increased thermal efficiency. The estimated consumption of natural gas will be about 17,000 cu ft per ton of iron produced. The plant is scheduled for operation in the latter part of 1959.

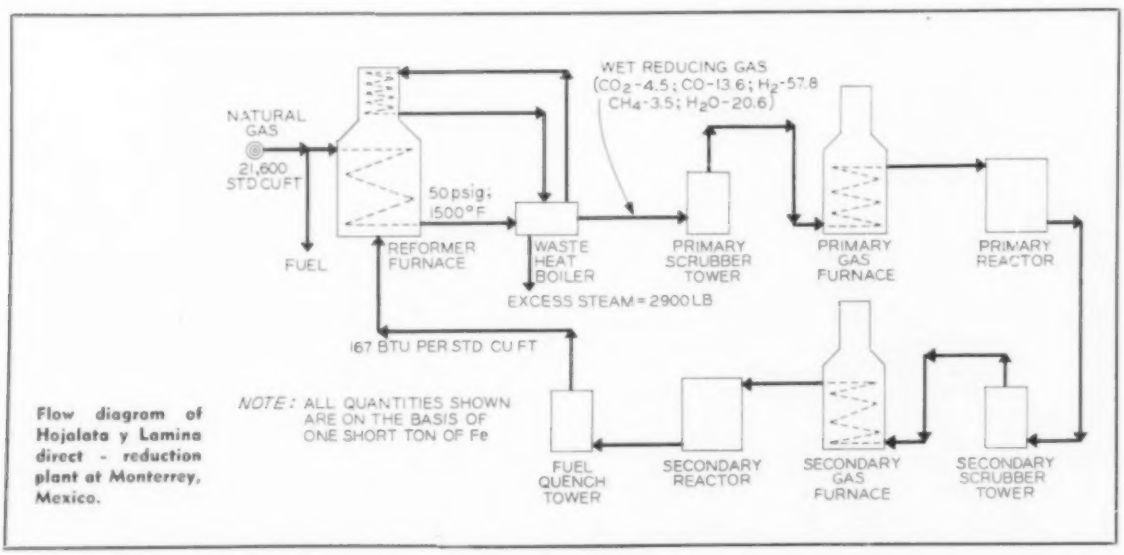
Processes under development

Ontario Research Foundation believes gas analyses high in carbon monoxide are preferable to those analyses rich in hydrogen. Less heat has to be supplied to the reduction reaction, and the resulting product has a higher carbon content, making it more satisfactory as a melting stock. The choice between methods of gas generation depends entirely upon the local economics, available fuels, and the practical difficulties which may be encountered with heating and sticking of the charge in the reduction furnace, particularly when a high hydrogen gas is used.

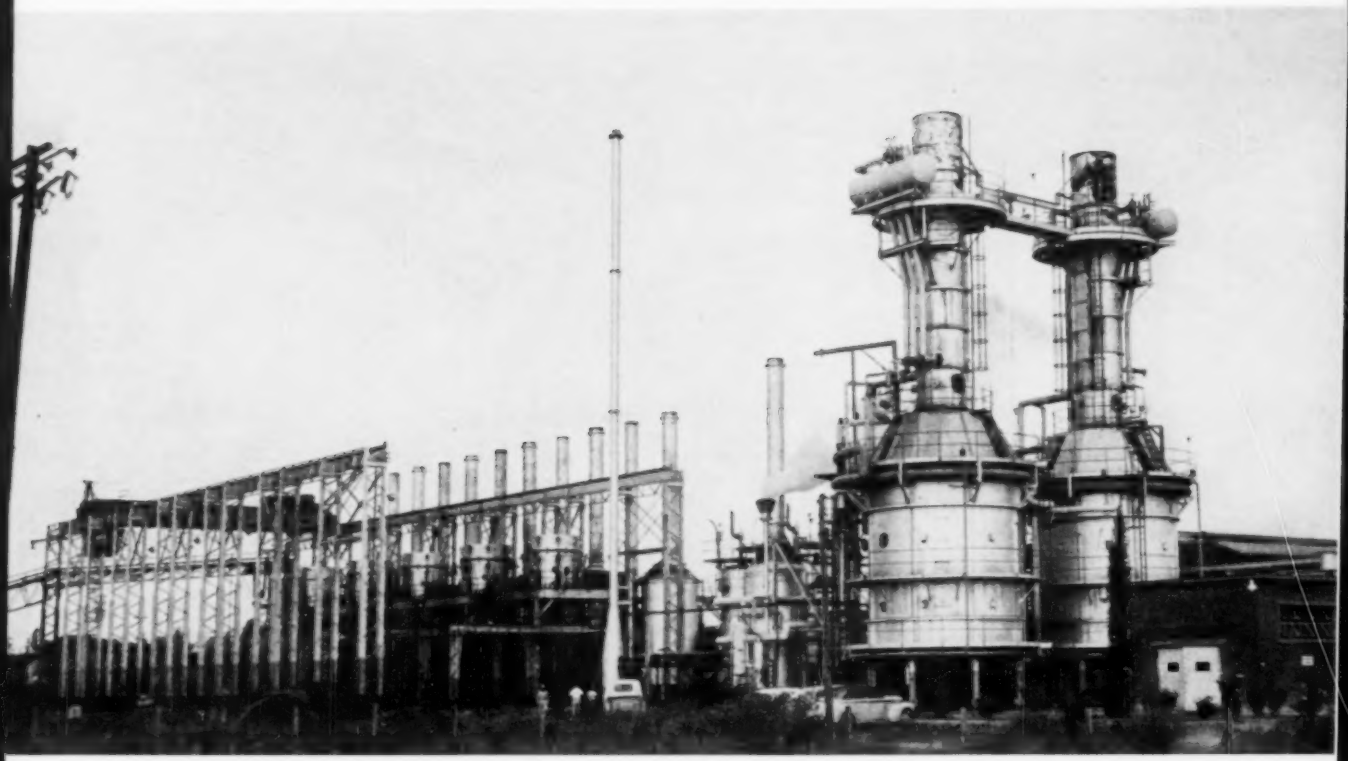
Hot, reduced iron ore is very sticky. This causes a great deal of difficulty, due to sticking and agglomeration of the charge in several types of reduction furnaces. It is preferable, therefore, that iron ore should not be moved with relation to its container during the course of reduction. With the exception of the Madaras process, which is similar to the Mexican sponge iron process, and of the MacDowell-Battelle process, in which a bed of iron ore and coal is partially reduced on a traveling grate, all of the processes under development on a large scale in North America do require movement of the reduced iron in relation to the reduction chamber. If reduction is carried out at relatively high temperatures over about 1500°F, sticking and agglomeration of the reduced iron can be expected unless means are provided to prevent this.

As a personal opinion, it is felt that fluidized bed techniques are not best suited to treatment of materials which change in density during treatment. Since the reduction of iron ore results in a change of about 25 pct in density in each particle, and since fine particles will reduce and change in density faster than coarser particles, it can be expected that trouble will be encountered in maintaining a uniform fluidized bed on a large scale during reduction.

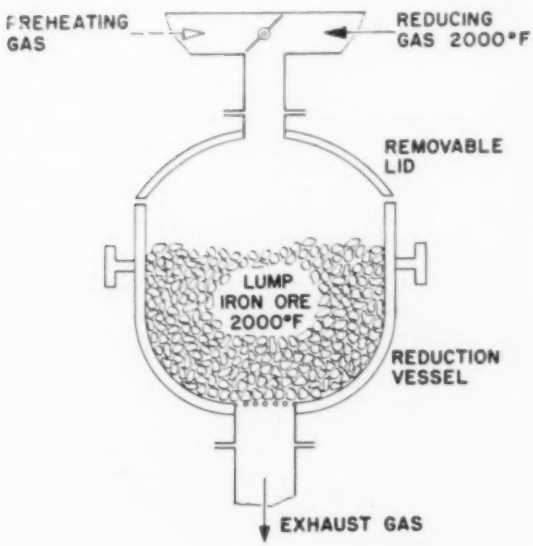
For these reasons, the Ontario Research Foundation has not spent much time in investigating the possibilities of fluidized bed reduction of iron ores. This field is being quite adequately covered by the development of such processes as the H-Iron process, the Arthur D. Little process, and U. S. Steel Nu-Iron process. The study of methods of supplying and regenerating reducing gas for these processes is

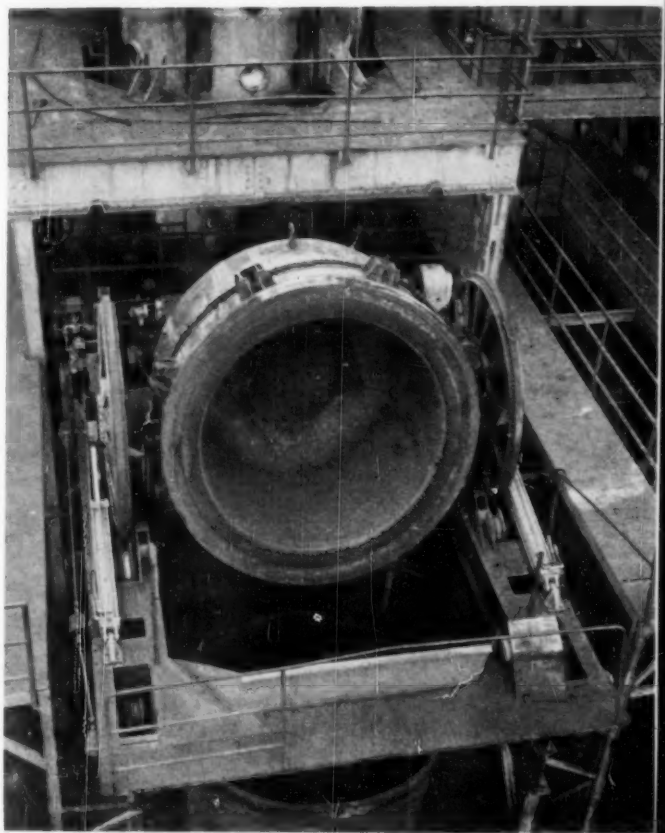


Flow diagram of Hojalata y Lamina direct - reduction plant at Monterrey, Mexico.



At the Hojalata y Lamina plant, Durango hematite ore is reduced in fixed-bed batch-type reactors by a reformed natural gas containing approximately 85 pct H_2 and CO. Shown above is the 200 tpd plant, while the reactors are shown in the illustration below. Photographs courtesy M. W. Kellogg Co.





a most valuable contribution to this field of knowledge. Of particular interest is the experience being gained with the fluidized bed process installed by Kellogg in Rhodesia to make 80 tons per day of reduced iron for cementation.

In the **H-iron** process, it has been possible to operate at such a low temperature of 900°F that sticking difficulties in the fluidized bed are avoided. In order to maintain a reasonable reaction rate, it is necessary to operate at high pressure in the H-iron process, so that a batch reduction time of about 4 hr is achieved. The same reaction time can be obtained without the use of high pressure, if a reduction temperature between 1500° and 2000°F is used, and means are employed to minimize sticking and agglomeration in the fluidized bed.

Plans are under discussion to try some of these processes on a large scale. It is not yet possible to determine whether or not the inherent inhomogeneity of a partially reduced fluidized bed of iron ore particles will cause serious operating difficulties on a large scale until such tests have been run.

Sponge iron as melting stock

Very few people today know whether or not they actually would like to use sponge iron as melting stock and what price they could afford to pay for it in their own shop. We believe the product should have as high a density as possible with less than 3 pct Si and a carbon content between 0.5 pct and 1 pct for easy melting. The estimated cost of sponge iron from the four operating commercial processes ranges between $45 and $55 per ton of metallic iron for most locations in North America. This limits its use as a scrap substitute to times when scrap prices are relatively high.

It is possible to arrive at a rough estimate of the savings in steel plant operations which could be achieved if difficulties due to high residuals were completely eliminated. Improvements in steel quality are difficult to evaluate in dollars, but the amount of lost time and material due to rolling, forging, and annealing difficulties can be arrived at in most plants. This saving would then represent the premium which could be reasonably paid for sponge iron above the price of scrap.

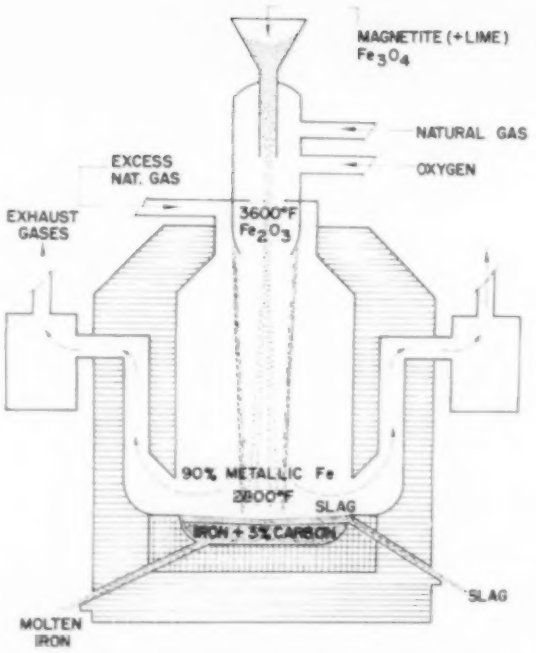
The fact that sponge iron melting-stock is more valuable than scrap is clearly recognized in Sweden, where most experience has been gained in the use of sponge iron melting-stock.

Sponge iron cannot be charged and refined in exactly the same way as scrap, and attempts to do so generally lead to very discouraging results.

Ontario Research Foundation developments

It is an advantage to reduce iron ore particles in as small a size as possible. With the present and future production of large tonnages of fine magnetite concentrates, it would be technically and economically desirable to reduce these concentrates in the fine state rather than agglomerating them before reduction. This is, of course, the reason for the major interest in development of fluidized bed techniques for direct reduction.

At some locations, fuel economy may be less important than iron output per dollar invested in equipment. In such cases a high production rate, due to fast reaction times (which can be gained only at the expense of fuel economy), may be worthwhile. Extremely high reaction rates can be obtained by contacting hot unreduced iron ore with rich hot reducing gas.



The Jet Smelting process in its initial stages of development at Ontario Research Foundation utilizes high temperatures for rapid direct-reduction of iron ore by natural gas.

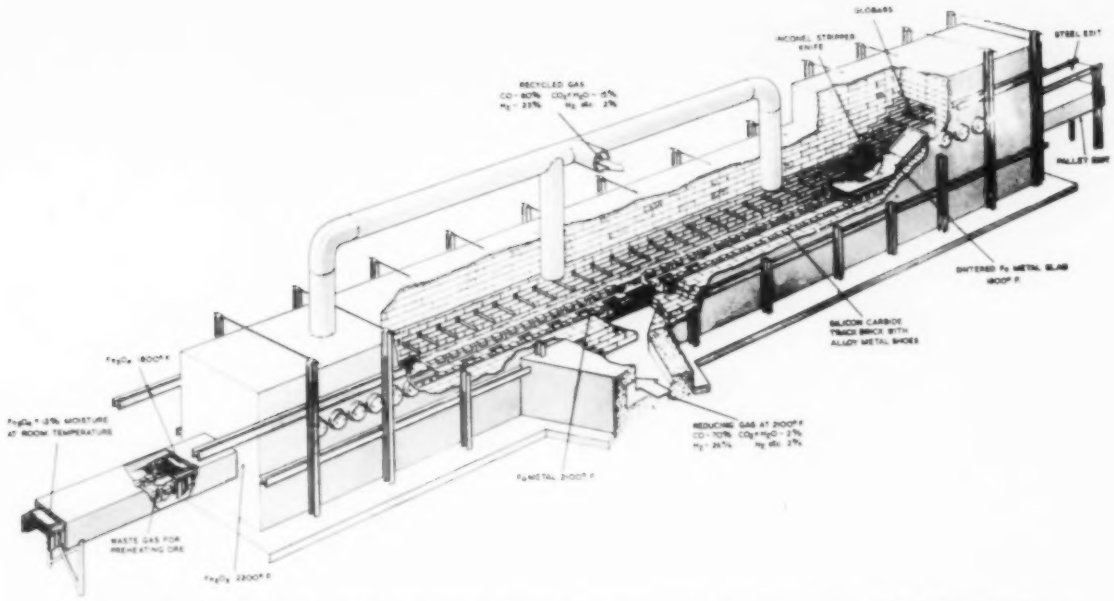
Two methods of applying these principles are being studied at Ontario Research Foundation.

O. R. F. direct steel process

This process has been under development for six years. A bed of fine magnetite superconcentrate is laid down on a traveling grate and heated to about 1800°F by waste gas from the reduction furnace. The hot magnetite burns to hematite, raising the temperature very rapidly to about 2200°F. The resulting bed has high permeability and is lightly fused together so that high rates of gas supply can be achieved without excessive dusting or blowing of the ore. Reducing gas at about 2000°F and 3:1 CO:H_2 ratio is forced to pass through the grate and the ore bed. Reduction to FeO is very rapid, and reduction is complete in well under 1 hr. The bed of reduced iron is in the form of a hot sintered metallic cake, which can be stripped from the traveling grate at a temperature of about 2000°F; this is a satisfactory temperature to allow hot rolling in one single pass to a usable steel sheet about 1/10 the thickness of the original low-density slab.

In the development of this process, one basic idea has been that, provided a sufficiently clean concentrate could be completely reduced to metallic iron, there was no point in cooling it and selling it for melting stock if it could be processed to a finished product selling for twice the price.

Since little of the reducing power of the gas is used on passage through the ore bed, the exhaust gas from the furnace is still a rich fuel gas. The choice between recirculating some of this gas or using it as fuel in other operations is a matter of local economics.



The Ontario Research Foundation direct steel process utilizes a bed of magnetite super-concentrate, which is burned to hematite, reduced by gas, and rolled into steel sheet. This process is still in the development stage under the sponsorship of Republic Steel.

This process is still in the development stage, under the sponsorship of Republic Steel. It his been mentioned here only to illustrate the application of some of the principles that have been outlined above.

The process is limited strictly to the use of ores which can be concentrated to a purity of 0.5 pct gangue or less and to the production of sheets 3 ft or less in width, by 0.25 in. or less in thickness, and of rod and wire of less than 1 in. diam.

Excellent control of carbon content has been achieved by control of the carbon dioxide content of the reducing gas. Some alloying elements, such as nickel and cobalt can be reduced from the oxides, while others, such as manganese and chromium must be added as ferro-alloys.

Jet smelting

The improvement in reduction time of fine iron oxide from about 4 hr in several processes under development to about 1 hr in the Direct Steel process led to consideration of even faster reduction times. At high temperatures, reduction is very rapid indeed. The fact that a molten product is produced at high temperatures is an advantage, since the production of the highest density melting-stock is a desirable objective.

The Cyclosteel process under investigation in England is following this line of development, with the object of producing a molten metal from fine iron ore and coal.

In the Ontario Research Foundation approach to this new type of direct reduction process, we have a definite objective in trying to provide a method utilizing only natural gas and fine iron ore concentrate to make a molten melting-stock at mine sites in northern Ontario. This appears to be quite possible if fine magnetite concentrate is entrained in a high-temperature flame of oxygen and natural gas. The temperature of the ore particles is raised quickly to about 3500°F by combustion of the magnetite. At the same time the individual particles decrepitate, due to the rapid heating, and create a great deal of new surface. The hot hematite is then contacted by a large excess of natural gas which cracks to form carbon monoxide and hydrogen in contact with the hematite. If the resulting flame with extrained dust is fired vertically downward into a bath of molten metal and slag at sufficient velocity, dust losses are kept within reason.

In order to carry out the last stages of reduction in reasonable time, the bath is maintained at a high carbon content so that final reduction to metal takes place in the slag cover over the molten bath. Production of a high-carbon metal has the additional advantage that furnace temperatures are of about the same order as in an open-hearth or electric steelmaking furnace. Since this type of operation avoids impingement of iron oxide on the refractories, reasonable refractory life is expected.

The objective of this process is to obtain the greatest possible production from a given furnace and to use sufficient fuel so that the waste gas and waste heat from the furnace are, at least, sufficient to provide the required energy to make oxygen to supply the furnace. The problem is in using enough fuel in the process to provide this required energy and, if possible, to have additional oxygen available to make low-carbon melting-stock outside the furnace if desired.

This process is in the initial stages of development.

Conclusions

Higher capital costs, increased use of fines, and availability of lower grade iron ores, as well as increases in scrap prices have caused a second look into the possibilities of direct reduction of iron ores. Further impetus has been derived from the desire to produce steel in regions lacking supplies of traditional metallurgical fuels.

The direct reduction tools have, thus, been developed. Today they are being used in certain areas, and future developments are likely to be in the direction of increased usage of these new techniques.

PINHOLE POROSITY IN HIGH-ALLOY STEEL CASTINGS

Pinhole porosity in castings made in green sand molds is one of the hazards which has confronted industry for many years. Much has been written about this problem in carbon and low-alloy steels, but this paper considers the same occurrence in high-alloy steels.

by R. J. Mangone, A. M. Hall, W. T. Bryan, and C. E. Sims

A major problem in the high-alloy steel casting industry for many years has been the occurrence of pinhole porosity in green sand mold castings.

A measure of relief has been brought about by the use of small additions of selenium to the melt.[1] While the mechanism whereby selenium reduces or eliminates porosity is not known, there is ample evidence to demonstrate that, under the proper conditions, the addition is effective.

On the other hand, the large number of factors in high-alloy foundry practice that may influence the formation of pinhole porosity has, in many cases, tended to obscure their relationship to the phenomenon. The cause-and-effect relationship between many of these factors and the incidence of pinholes has not been thoroughly understood. For these reasons it appeared appropriate to investigate pinhole porosity in stainless-type steels made in green sand molds.

Earlier research

It is of interest to consider a mechanism for the formation of pinhole porosity based on some earlier research.[2-3] According to a theory proposed by Sims, when molten steel is poured into a green sand mold, a thin skin of metal quickly freezes adjacent to the mold wall. At the same time, the nearby moisture in the mold is converted to steam by the heat from the metal, with a large increase in volume. Much of the steam diffuses back into the mold. However, some of it comes into intimate contact with the outer surface of the skin of frozen metal. Here, it reacts with the metal to form a film of metal oxide on the skin and atomic hydrogen.

The atomic hydrogen penetrates the skin of frozen metal and concentrates in the still-molten metal immediately behind the solid skin. When the concentration of hydrogen in the molten metal immediately behind the frozen layer becomes high enough, the hydrogen will react with oxygen (oxides) in the melt to form water vapor.

Because it is insoluble in molten steel, the water vapor takes the form of minute bubbles which usually appear in the hydrogen-rich region at the solid-liquid interface. The concentration of hydrogen in these bubbles initially is zero, while the concentration of hydrogen in the surrounding molten metal is a finite number and has an escaping pressure considerably above 1 atm. Therefore, it moves toward equilibrium by diffusing into the steam bubbles where it precipitates as molecular hydrogen. The water vapor bubbles act as nuclei for the precipitation of dissolved hydrogen from the molten metal, as well as for the additional hydrogen diffusing through the solidified skin of metal.

As the hydrogen continues to precipitate into the bubbles, the bubbles continuously get bigger. Because the metal is freezing during the process of bubble nucleation and growth, the bubbles elongate in the direction of freezing. Frozen metal constitutes their side walls, while the interface between the bubble and the still-molten metal advances into the melt. In this way the bubbles develop the characteristic shapes observed in castings containing pinhole porosity.

It should be noted that, in the description of pinhole porosity given here, the porosity does not start at the surface of the casting. Instead, it begins behind the skin that freezes when the metal is first poured into the mold. Thus, it is not visible in castings as shaken out of the molds. Subsequent heat treating and cleaning operations may break the thin wall of metal between the pore and the surface, thus making the porosity visible. It is then observed as a small round hole at the surface of the casting. The appearance of such holes has given rise to the term, *pinhole porosity*.

Occasionally, porosity in the form of small holes is visible in castings as shaken out. In these cases, it is possible that the frozen metal skin was ruptured at a point of imperfection by the pressure of the steam in the mold. The steam may have entered the metal in considerable quantities through these ruptures and been responsible for the porosity.

Water vapor, hydrogen, and oxygen

This description of the mechanism of pinhole formation in steel castings poured in green sand molds suggests that water vapor, hydrogen, and oxygen play critical roles. Formation of water vapor bubbles in the molten metal by the reaction of hydrogen

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with oxides in the melt seems necessary in most cases. If minute bubbles of water vapor did not form to nucleate hydrogen precipitation, the development of pinhole porosity would be unlikely. However, the formation of the necessary water vapor in the melt depends on the concentration of hydrogen and the availability of oxygen in the molten metal. If insufficient hydrogen is present, or if the oxygen in the melt is unavailable (i.e., combined as an oxide not readily reduced by hydrogen) these elements will not react to form the water vapor necessary to initiate porosity.

Hydrogen: Two general factors seem to contribute toward the hydrogen content of the melt immediately behind the skin of frozen metal. One is the concentration of hydrogen in the metal being poured into the mold. This is the hydrogen introduced in the melt during the melting campaign, and subsequent teeming and pouring. This concentrates on the freezing face by dendritic segregation. The other factor is the contribution made by hydrogen diffusing into the melt through the freezing skin, a product of the reaction between the metal and the steam from the mold.

These two factors are probably additive. Thus, if the initial hydrogen concentration in the metal entering the mold is low, more hydrogen must be supplied by the steam-metal reaction at the mold-metal interface to build up the hydrogen concentration to the point where hydrogen will react with the oxides in the melt to form water vapor. Conversely, the higher the initial hydrogen concentration in the metal, the less hydrogen is required from the steam-metal reaction. Therefore, with a melt of sufficiently low hydrogen content, a certain amount of mold moisture can be tolerated without the development of pinhole porosity. By the same token, with dry enough molds, it is possible to tolerate a considerable concentration of hydorgen in the metal in the ladle. In these ways, mold moisture and initial hydrogen content of the melt are interrelated in the development of pinhole porosity.

Oxygen in the melt is necessary to the formation of water vapor bubbles required to nucleate porosity. If this oxygen is unavailable, the water vapor bubbles cannot form and porosity will not develop. Some oxygen is inevitably present in melted stainless steel, and exclusion of it from the melt is impractical. However, it would appear that its availability for the formation of water vapor could be altered. Speaking very generally, the availability of oxygen in a melt consisting essentially of iron is relatively high. When silicon is added to the system, the availability is substantially reduced. When sufficient aluminum, titanium, or zirconium is added, the availability of oxygen may become extremely low. Both experiment and practice demonstrate that proper and thorough deoxidation of the melt offers an effective means of controlling the incidence of gas porosity in carbon and low-alloy steels.

By the same token, it would seem logical to speculate that pinhole porosity in stainless steels could be brought under control by the use of strong deoxidizers. This proposition was tested. Aluminum additions of up to 0.6 pct were made to 200-lb experimental melts of the 21 Cr-9 Ni casting alloy, Grade CF-8. No beneficial effects were observed relative to the incidence of pinhole porosity. It was evident that this strong deoxidizer behaved differently when added to the stainless steel than when added to steels of relatively low-alloy content.

Investigation of the AISI 310-type stainless steel by Perkins and Binder, appear to cast light on this difference in performance.[1] Their data suggest that, while additions of aluminum and other strong deoxidizers lower the oxygen content of stainless steels considerably, such additions do not reduce the oxygen level to the low values attained in the less highly alloyed steels. Therefore, it might be postulated that even strong deoxidation does not make oxygen sufficiently unavailable in stainless steels to prevent combination with hydrogen to form water vapor bubbles. Furthermore, when sufficient deoxidizer is added to cause appreciable lowering of the oxygen content, it tends to form nitrides. Thus, it adds undesirable inclusions and depletes the steel of nitrogen needed to stabilize the austenite. This is especially pronounced with titanium and zirconium. Thus, it seems advisable to consider other approaches to the problem of pinhole porosity in stainless steels.

Nitrogen dissolved in molten steel may also play a part in the development of pinhole porosity. However, the tolerance of stainless steel for nitrogen is comparatively high, and it is doubtful that this element plays a major part in pinhole formation in such steels except under unusual circumstances. It appears likely that dissolved nitrogen will precipitate into water vapor bubbles, just as hydrogen does, if it is available. In this way, nitrogen may contribute to gas porosity. However, dissolved nitrogen seems much less *available* than dissolved nitrogen. It would appear that the presence of chromium in the alloy influences the availability of nitrogen to precipitate into gas bubbles, and the higher the chromium content, the higher must be the concentration of dissolved nitrogen before it contributes to gas porosity. Austenite has a definitely higher solubility for nitrogen than does ferrite. When such elements as titaninum are added to the melt in the proper amounts, the nitrogen becomes virtually unavailable because it forms stable titanium nitrides.

Selenium additions

It has been demonstrated that a small addition of selenium to stainless steel melts can alleviate or eliminate pinhole porosity in castings made in green sand molds. The mechanism by which selenium does this is not known, but it is possible to speculate from either a chemical or a physical viewpoint. Three possible chemical mechanisms are conceived: selenium might eliminate hydrogen from the metal, possibly in the form of a hydrogen selenide gas; selenium might reduce water vapor formed in the melt and thus prevent it from nucleating porosity; or, it might hold hydrogen in the metal, possibly dissolved in selenide inclusions, thus making it unavailable to react with the oxides in the melt to form the water vapor bubbles that trigger porosity.

Several observations suggest that the first possibility is not correct. First, thermodynamic calculations indicate that the direct combination of selenium and hydrogen to form hydrogen selenide at steel-melting temperatures is unlikely. Second, expulsion of hydrogen from the melt in this manner would entail the loss of selenium. However, selenium recovery in the metal is usually 100 pct when added in the small amounts used for porosity control. In addition, if hydrogen is removed by the addition of selenium, a boil should occur following the addition. Such a boil has not been observed. Furthermore, there is experimental evidence that

hydrogen is not lost when selenium is added to the melt.

The second possibility is also unlikely. It requires that selenium be a powerful deoxidizer, and evidence is to the contrary. Thus, if the chemical viewpoint is to prevail, it must depend on the third possibility or some similar mechanism.

The physical hypothesis postulates that the presence of selenium in the molten metal prevents bubbles from forming in some way. It is possible, for example, that selenium influences the surface tension characteristics of the liquid metal in such a manner as to discourage steam-bubble formation. It is extremely difficult for gas bubbles to form in molten steel. They must usually nucleate on a solid surface of very irregular contour. The melt side of the skin of metal that freezes against the mold wall when the casting is first poured would be a surface with the required irregularity of contour. However, it is conceivable that even a moderate decrease in the surface tension of the steel would considerably reduce the probability of bubble formation.

Although observations made in the course of the experimental work do not definitely prove or disprove any of these suggested mechanisms, they strongly discourage a chemical explanation of the effect of selenium.

Laboratory experiments

As a prerequisite to the investigation, it was necessary to know whether pinhole porosity observed in the foundry could be regularly produced and controlled in the laboratory. Therefore, a series of preliminary experiments was performed to observe the effect of several factors on the formation of pinhole porosity. The objective was to reproduce the phenomenon in the laboratory under controlled conditions. Since hydrogen and water vapor appeared to be important variables, the experiments were designed to determine their effect over a wide concentration range.

The procedure used was to melt virgin stock in a magnesia-lined induction furnace to provide melts in the CF-8 alloy composition range. The hydrogen content of the melts was varied from 4 to 18 ppm by bubbling tank hydrogen through the molten metal. Castings were poured into calcined clay and core sand molds, and into green sand molds of varying moisture content to observe the effect of mold moisture. All of the castings in this preliminary work were poured at a temperature of 2900°F as measured by an optical pyrometer.

A gland casting (Fig. 1) was used to observe the extent of porosity under the various conditions. This particular shape was reported from practice to be very susceptible to the formation of pinhole porosity in the four thin ear sections. Radiographs were made to show the extent of pinhole porosity (Fig. 2 and 3).

The results showed that pinhole porosity could be produced readily in the laboratory, and indicated the importance of the hydrogen content of the melt and the moisture in the mold. The severity of the porosity increased with the moisture content of the core sand and green sand molds. No porosity was found in the calcined clay molds (zero moisture content) even though the hydrogen content of the metal ranged up to 18 ppm. However, in castings made in green sand molds, the degree of porosity was more severe as the hydrogen content of the melt was increased.

The effectiveness of ferroselenium additions in controlling porosity was also confirmed in the laboratory. It was interesting to note that the hydrogen contents of the melts were not altered by the selenium additions.

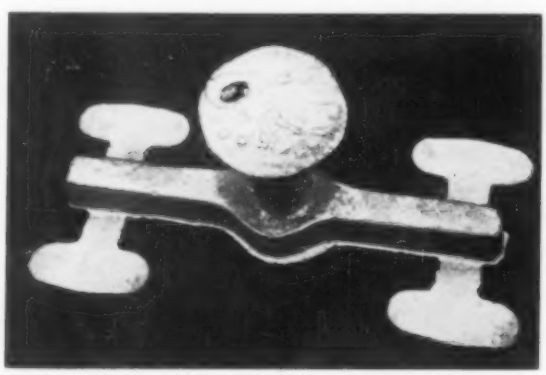

Fig. 1—Gland casting used to observe the extent of porosity.

Hydrogen and temperature

Preliminary results suggested the advisability of establishing quantitatively the interrelated effects of melt-hydrogen content and pouring temperature. Such information would be useful in evaluating the effects of other variables.

The procedure used was to induction-melt a series of 200- to 240-lb heats of CF-8 alloy. After meltdown, the hydrogen levels were adjusted by bubbling tank hydrogen into the melts at approximately 3100°F for various periods of time. To determine the effect of pouring temperature on the incidence of porosity, the melt was allowed to cool, and metal was poured directly from the furnace into the molds

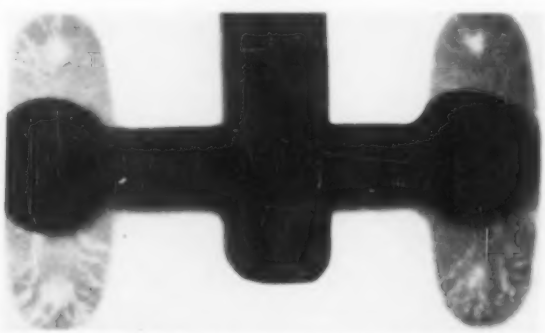

Fig. 2—Radiograph showing a medium degree of porosity.

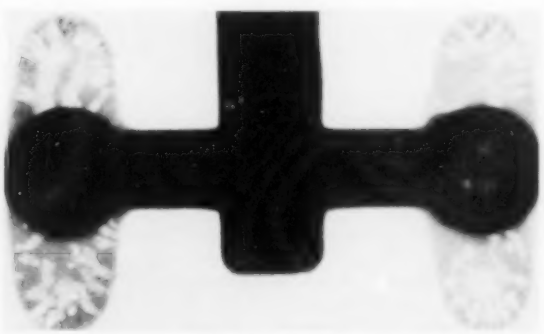

Fig. 3—Severe porosity.

as the desired temperatures were reached. Pouring temperatures were measured in the furnace with immersion thermocouples.

Samples for hydrogen analysis were taken at various intervals during the pouring of a series of castings. In some cases, metal remaining in the furnace, after one series of castings was made, was reheated for subsequent tests. Additions of selenium (when used) were made just prior to the beginning of the cool-down. Castings were poured into molds containing 3 and 4.5 pct water. The molds were squeezed to a hardness that would give them a permeability in the 120 to 130 range (determined from a curve of hardness versus permeability). The castings were radiographed to determine the extent of porosity.

The results obtained are plotted in Fig. 4 in such a way as to show whether the castings were porous or sound. In each case, it was possible to draw a line separating the areas representing the conditions under which sound or porous castings would be expected. This chart shows that porosity could be developed by increasing either the pouring temperature or the melt hydrogen content. The slopes and shapes of the lines separating the conditions under which sound castings result from those under which porous castings result indicate the relative importance of temperature and hydrogen content. The effect of mold-moisture or selenium additions is indicated by the displacement of the lines from those used for comparison.

The effect of increasing the mold moisture from 3 to 4.5 pct in the absence of selenium was to narrow the area which is termed *sound castings*. This means that the melt hydrogen content or the pouring temperature must be lower when higher mold moisture contents are used. Castings produced in molds containing 4.5 pct moisture were more sensitive to small variations in melt hydrogen content than those produced in molds containing 3 pct moisture. This is shown by the difference in the slope of the lines.

This interrelated effect of mold-moisture content, melt hydrogen content, and pouring temperature is especially significant, because the two curves surround an area which encompasses a range of hydrogen content and pouring temperature that is expected in commercial practice. Thus, it is evident that close control of these variables within the proper limits may be required for the commercial production of sound castings.

The beneficial effect of selenium at both the 3 and 4.5 pct mold-moisture conditions is shown in the plot. In each case, the effect of selenium was to shift the position of the dividing lines to the right so that more melt hydrogen can be tolerated and higher pouring temperatures may be used. The amount of shift produced by an addition of 0.02 pct selenium was much greater at the 4.5 pct mold-moisture level than at the 3 pct level. This is illustrated by the curves at 2850°F.

The effect of changing the mold moisture from 3 to 4.5 pct was not apparent when a 0.02 pct selenium addition was used. That is to say, the curves under these conditions were nearly identical. This indicates that the detrimental effect expected from the higher mold-moisture content was not observed. Evidently, the beneficial effect of the selenium addition was such that it overshadowed the detrimental effect of the increased mold moisture.

Mold permeability

The results obtained during the experiments which were concerned with the plotting of the melt hydrogen versus pouring temperature curves indicated that mold permeability might be a variable to consider in the porosity studies. Accordingly, experiments were performed in which mold permeability was varied.

Castings were made in molds, the permeabilities of which were in the 80-90, 120-130, and 160-170 ranges. Permeability was controlled by first determining a hardness versus permeability curve for the sand mixture, and then squeezing the mold to the hardness necessary to give the desired permeability, as indicated by the hardness. Pouring temperatures were selected on the basis of the previous work so that the dividing line between porous and nonporous conditions would be traversed.

No clear-cut effect of permeability was observed either when the mold moisture content was 3 pct or

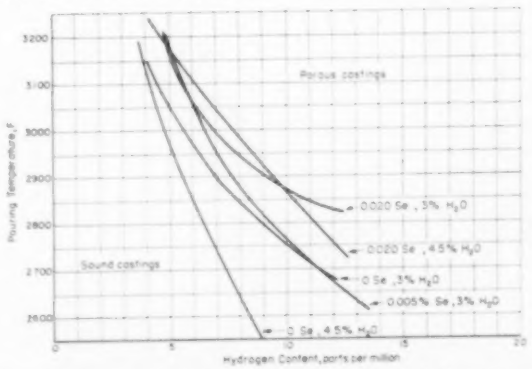

Fig. 4—Influence of pouring temperature and melt-hydrogen content on the occurrence of pinhole porosity in molds of 120 to 130 permeability.

Table I. Hydrogen Content of Samples Taken From Arc-Melted Heats[a]

Description of Sample	CF-8 Alloy Co. 1 Heat 1	CF-8 Alloy Co. 1 Heat 2	CF-8 Alloy Co. 1 Heat 3	CF-8 Alloy Co. 1 Heat 4	CF-8 Alloy Co. 2 Heat 1	CF-8 Alloy Co. 2 Heat 2	CF-8M Alloy Co. 3 Heat 1	CF-8M Alloy Co. 3 Heat 2	HF Alloy Co. 4 Heat 1	HT Alloy Co. 5 Heat 1
Meltdown	5.5	5.2	5.7	5.8	9.9	5.6	9.4	7.4	—	3.2
Before oxygen blow	—	—	—	—	—	—	7.0	7.8	—	—
After oxygen blow	2.0	0.7	2.3	0.9	3.1[b]	5.0[b]	2.4	4.6	7.8	—
After Cr addition	—	—	—	—	—	—	2.5	5.6	—	—
After refining before tap	—	2.9	2.8	5.5	—	—	3.8	5.5	6.2	3.4
Bull ladle	—	—	—	—	—	—	—	8.0	—	—
Bull reladle	—	—	—	—	—	—	7.2	9.6	—	—
First shank ladle	3.5	3.8	4.3	3.8	3.1	4.4	—	7.9	—	3.8
Last shank ladle	—	—	—	—	2.6	3.3	—	—	—	—
Mold riser	7.6	5.6	6.0	7.0	—	—	—	—	—	—

[a] Hydrogen content reported in ppm.
[b] Also carbon boil.

when it was 4.5 pct. It is surmised that considerably lower permeabilities would have been required for this variable to influence the incidence of pinhole porosity.

Field experience

To evaluate the laboratory investigation of pinhole porosity in terms of commercial foundry practice and experience, field experiments were carried out to gain information on the range of meltdown hydrogen contents to be expected, and the influence of foundry operations on melt hydrogen content.

Several Alloy Casting Institute members provided samples from various heats for hydrogen analysis at Battelle. The samples were taken from arc-melted heats of CF-8, CF-8M, HF, and HT alloys and from induction-melted HF, HH, HK, HU, HT, CF-8, and CF-8M alloys.

Samples from the arc-melted heats were taken at various stages during the melting campaign. The results show that the meltdown hydrogen contents varied from 3.2 to 9.9 ppm (Table I).This is a considerable spread and spans most of the range of melt hydrogen contents within which the laboratory work was done. The laboratory results suggest that, at the lower end of this spread, little difficulty would be expected, while at the upper end, troubles from pinhole porosity would be likely.

Where applicable data from the commercial heats were available, they demonstrated the ability of the oxygen blow to reduce melt hydrogen content. In most cases, the extent of reduction was dramatic. The oxygen blow certainly seems to be an effective means for obtaining a low hydrogen content during at least one period in the making of a heat of stainless-type alloy. In general, however, subsequent refining and ladling increased the hydrogen content over that prevailing after the blow.

These observations strongly emphasize the necessity of avoiding contact with moisture especially after the oxygen blow. Chromium and other alloy additions should be thoroughly dry, and slag-making materials should be completely free from moisture. Ladles are of equal importance; they are likely to contribute significant amounts of hydrogen unless preheated above 2000°F for several hours.[5]

An interesting point was brought out by analysis of mold riser samples taken before the metal froze. In every case where this was done, the hydrogen content was considerably higher than that in the metal before pouring. This adds evidence to the theory that the mold moisture contributes hydrogen to the molten metal before solidification.

Some samples for hydrogen analysis were submitted by several companies for induction heats of various alloys. A tabulation which presents the results of the hydrogen determinations made on these samples is given in Table II.

The only conclusion to be drawn from these results is that they probably indicate the levels of hydrogen to be expected in normal induction practice.

Table II. Hydrogen Content of Samples Taken from Induction Heats[a]

Alloy Type	Description of Sample	Co. A Heat 1	Co. A Heat 2	Co. B Heat 1	Co. B Heat 2	Co. B Heat 3	Co. B Heat 4	Co. B Heat 5	Co. C Heat 1
HF	Tap ladle	3.2	—	—	—	—	—	—	—
CF-8	Meltdown	—	—	—	2.3	—	—	—	—
CF-8M	Ladle	—	—	—	—	—	—	—	2.5[b]
HH	Meltdown	—	—	3.9	—	—	—	—	—
HK	Ladle	—	2.4	—	—	—	—	—	—
HK	Furnace before tap	—	5.0	—	—	—	—	—	—
HU	Meltdown	—	—	—	—	3.9	—	—	—
HT	Meltdown	—	—	—	—	—	3.6	3.3	—

[a] Hydrogen content reported in ppm.
[b] Average of four samples.

The important variables

Results of this investigation show that the important foundry variables influencing pinhole porosity in stainless-type castings are melt hydrogen content, pouring temperature, and mold-moisture content. Careful control of these major variables will minimize the occurrence of pinhole porosity in castings under normal conditions. The curves that show the relationship between pouring temperature and hydrogen content of the melt at several selenium and mold-moisture contents can constitute a useful guide for improving foundry practice. These were obtained for the CF-8 alloy and may apply only in a very general way to other high-alloy grades.

The position of the lines of demarcation between porous and sound casting conditions were established as a result of numerous experiments made over a period of about 1½ years. Thus, they can be considered to have some quantitative meaning, and might be used to select conditions for sound castings within the limits set by the experiments. For example, the interrelated effects of melt hydrogen and pouring temperatures are shown for castings made in molds containing either 3 or 4.5 pct moisture. If the hydrogen content is known, the curves will indicate the maximum pouring temperature that should result in sound castings when poured in molds in the indicated range of water content. At other mold-moisture levels, the curves would no longer apply. Within reasonable limits, perhaps some extrapolation could be made. Beyond such limits new curves would have to be prepared from results of additional experiments.

This type of plot indicates what control is necessary of both melt hydrogen content and mold moisture to achieve sound castings. Also, it points the direction for overcoming the harmful effect of one variable by compensating with a change in the other variable. Thus, if weather conditions (i.e., humidity) should prevent the control of melt hydrogen within a desired low range, it may be possible to minimize porosity by reducing the mold moisture, or by pouring at a lower temperature if practicable.

Another useful application of the curves is the evaluation of the effect of changes in practice. For example, the curves show that the addition of 0.02 pct selenium permits more hydrogen in the melt and higher pouring temperatures before conditions resulting in porous castings are reached. Similarly, the detrimental effect from high moisture content of the molds, within the range investigated, can be compensated by the selenium addition. In the absence of selenium the moisture content of the mold becomes more important.

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STEEL QUALITY CONTROL USING THE ARL QUANTOMETER

During the past few years, the use of recording photoelectric spectrometers for the production control of electric and open-hearth furnaces has become increasingly prominent throughout the steel industry. This method of analysis now supplements, and in some cases has replaced, wet chemical and photographic spectrochemical methods.

by H. C. Brown

WHILE still in its infancy, the direct-reading method of analysis was questioned from the standpoint of accuracy, operating costs, furnace time saved, freedom from breakdowns, and reduction in manpower. The main emphasis in favor of a shift to direct-reading equipment was based on three factors: furnace time saved, decrease in operating costs, and reduction in man power.

The purpose of this paper is to show the accuracy that has been obtained for the alloying elements in stainless, low-alloy, and carbon steels using the Applied Research Laboratories' 1.5 m Production Control Quantometer. This study pertains to the installation at the Butler works of Armco Steel Corp. and covers a period of the last five years.

A description of the apparatus, excitation and line pairs used, and method of calculation will not be provided, since this information was reported by the author in a previous paper.[1]

The Quantometer has been notably free of breakdown since placing it on production control five years ago. The preliminary samples from only one stainless steel heat have had to be analyzed by wet chemistry because of instrument trouble. Approximately 5000 stainless steel heats from the 70-ton electric furnace and 10,000 low-alloy and carbon steel heats from the open-hearth furnaces have been controlled during this time without delay. Minor delays have been experienced in the analysis of five low-alloy heats, and two low-alloy heats have had to be analyzed by wet chemistry. Calculated emergency down time for the five years of operation is less than 26 hr.

The Quantometer has lessened the time per heat of stainless steel such that approximately 4500 additional tons have been tapped yearly since the instrument was placed on production control; it has reduced cost of analyses; and it has reduced the laboratory force.

The ARL Production Control Quantometer is being used for the determinations of nickel, chromium, manganese, silicon, and molybdenum on the preliminary tests of all stainless steel heats. On ladle tests the instrument is used for the determinations of manganese, silicon, copper, lead, tin, and molybdenum on all stainless steel grades, and nickel and chromium on most of the stainless steel grades. In the higher alloying grades, such as Types 309 and 310, nickel and chromium are still run chemically on the ladle tests. Aluminum, columbium, tantalum, tungsten, and cobalt are controlled when these types of stainless steel heats are made. The instrument is also used in reporting final results for silicon, manganese, chromium, nickel, molybdenum, tin, copper, and aluminum on all low-alloy and several carbon steel grades.

H. C. BROWN is works chemist, Butler div., Armco Steel Corp., Butler, Pa.

Precision

The precision of the quantometric procedure has been determined by making a reproducibility study of two standard samples: one a Type 304 stainless steel; the other a low-alloy steel. Data were obtained on these standard samples for a period of approximately two weeks. These two standard samples were representative of the standards used during the past five years. The elements studied were chromium in the stainless steel standard and silicon in low-alloy steel standard. The samples were sparked four times on 24 different occasions for a total of 96 individual sparkings. The calculated average concentration of chromium in the stainless steel sample used for the reproducibility study was 17.36 pct; for silicon in the low-alloy steel sample, 3.06 pct. Sigma was calculated for each element and found to be ± 0.068 pct for chromium and ± 0.027 pct for silicon. If the average of four sparkings is used, which is the number used for daily routine analysis, sigma for each element would be as follows: chromium, ± 0.034 pct; silicon, ± 0.014 pct. The coefficient of variation based on the 96 individual sparkings of the two standard samples was found to be 0.39 pct for chromium and 0.88 pct for silicon. Inasmuch as most of the variable conditions usually associated with the quantometric procedure were

encountered during this period of study, the reproducibility data for the two elements are believed to be quite representative of those to be expected over a long-term operation.

Accuracy

In order to determine the accuracy of the ladle test values reported by the works' laboratories, a check analysis system was initiated at Armco about 25 years ago. The present system involves monthly check analyses by the Armco Research laboratories of selected determinations from an entire day's production of heats and casts from each of the Armco works.

As a basis for determining when a particular value reported by the work's laboratory is in error, a table of standard analytical tolerances has been established. Table I shows the allowable tolerances for the elements discussed in this paper. The tolerance permitted varies with the element concerned, the percentage present, and the type of steel involved. For example, the tolerances permitted for a high-alloy steel, such as stainless, are sometimes greater than those for plain carbon steel. The value reported by the works laboratory is called in error if it is not in agreement with the Research value within the established tolerance.

The accuracy of the quantometric method has been determined by comparing the routine results obtained daily on the Quantometer with the results obtained by Research using referee chemical methods. A comparison of the results is shown in Tables II and III. The tables include all the data obtained on all ladle test samples analyzed by the Research laboratories during the past five years for the elements studied in this paper.

The following are some of the deviations from wet chemical values that were obtained:

1. Nickel (stainless steel types 410, 430, 430 Ti, 446): two quantometric values varied by more than ±0.020 pct Ni from the chemical value;
2. Copper (all stainless steel types): all quantometric values fell within ±0.020 pct Cu of the chemical values;
3. Molybdenum (stainless steel type 312): all values except one fell within ±0.060 pct Mo of the chemical values;
4. Manganese (low-alloy steel types): of 43 samples in which Mn was less than 0.10 pct, seven samples deviated by more than ±0.005 pct from the chemical values. Of 48 samples in which manganese was greater than 0.10 pct, only two samples deviated by more than ±0.01 pct from the chemical values;
5. Manganese (carbon steels): only one quantometric value varied by more than ±0.02 pct from the chemical value.

The data presented in the tables include errors from a number of variables, such as chemical errors, instrument errors, excitation errors, and segregation errors. However, to obtain the degree of accuracy shown in this study, another group of variables must be closely controlled; some of these are as follows:

1) Sampling,
2) Procedure in selecting and standardizing samples to be used as standards,
3) Surface preparation of standard and unknown samples,
4) Sharpening of graphite electrodes and electrode cutters,
5) Photo-tube characteristics, and
6) Standardized maintenance.

It is believed that good control over this last group of variables has been obtained. For instance, during 1953, which was the first full year of operation for the Quantometer, 83.9 pct of the quantometric results on stainless steel agreed with Research Referee results within the allowed tolerance. This percentage gradually increased during the next four years, hitting a peak of 96.6 pct during 1957.

Summary

The use of the ARL Production Control Quantometer for the analysis of stainless, low-alloy, and carbon steels has been discussed. The study covered a five-year period, during which time the quantometric results were compared with referee chemical results. The referee chemical results were determined by the Armco Research laboratories through the company's check analysis system. The results shown in this paper prove that the ARL Quantometer can be used with a high degree of accuracy for production control analyses.

[1] H. C. Brown: *Application of the ARL Quantometer to Production Control In a Steel Mill*, JOURNAL OF METALS, 1954, p. 349.

Table I. Standard Analytical Tolerances for the Armco Analytical Laboratories

Element	Range, Pct	Tolerance ±
	Stainless Steel	
Mn	0.10-0.49	0.02
	0.50-1.49	0.03
	1.50-2.49	0.04
Si	0.10-0.29	0.01
	0.30-0.99	0.02
Cu	0.10-0.39	0.01
Mo	1.00-1.99	0.04
	2.00-3.99	0.06
Ni (low)	0.10-0.29	0.01
	0.30-0.99	0.02
Ni (high)	6.00-7.99	0.07
Cr	8.00-9.99	0.08
	10.00-14.99	0.10
	15.00-29.99	0.15
	Low Alloy and Carbon Steels	
Mn	0.000-0.099	0.003
	0.10-0.39	0.01
	0.40-0.99	0.02
Si	0.30-0.99	0.02
	1.00-2.99	0.03
	3.00-5.99	0.04

Table II. Comparison of Quantometric Results With Referee Chemical Results on Stainless Steel Heats

No. of Samples	Element	Concentration Range, Pct	Avg Concentration, Pct	Avg Deviation from Chemical, Pct
148	Mn	0.22-2.00	0.71	0.016
128	Si	0.21-0.86	0.54	0.013
31	Cu	0.13-0.22	0.17	0.006
11	Mo	2.00-2.36	2.19	0.035
30	Ni	0.17-0.58	0.30	0.010
92	Ni	6.86-10.72	8.75	0.068
176	Cr	12.55-23.32	17.63	0.076

Table III. Comparison of Quantometric Results With Referee Chemical Results on Low-Alloy and Carbon Steel Heats

No. of Samples	Element	Concentration Range, Pct	Avg Concentration, Pct	Avg Deviation from Chemical, Pct
136	Si	1.09-3.36	2.66	0.028
115	Mn	0.069-0.43	0.17	0.005

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AIME NEWS

Metallurgical Society Plans Inclusive Annual Meeting Program in San Francisco

An outstanding technical program is planned by The Metallurgical Society of AIME for the Annual Meeting in San Francisco. Session titles have been announced by the Programs Committee of the three divisions, and are given below. All sessions will be held at the St. Francis Hotel, unless otherwise noted.

Sunday Afternoon, February 15

Metallurgical Society

1. Critical Issues in Metallurgical Education (Session organized by the Committees on Education and the Metallurgical Profession).

Monday Morning, February 16

Institute of Metals

1. "Interfaces and Surfaces."
2. Session based on research abstracts.

Joint Institute of Metals—Extractive Metallurgy

1. Plutonium Metallurgy I.

Extractive Metallurgy

1. Lead

Iron and Steel

1. Iron Ore Reduction.

Monday Afternoon, February 16

Institute of Metals

1. Observations of Dislocations.

Joint Institute of Metals—Extractive Metallurgy

1. Beryllium Metallurgy.
2. Plutonium Metallurgy II.

Extractive Metallurgy

1. Copper

Joint Extractive Metallurgy—Iron and Steel

1. Physical Chemistry of Blast Furnace Smelting.

(Continued on page 822)

AIME Awards for 1959 Presentation Announced

The following men have been selected for 1958-1959 AIME awards to be presented at the ceremonies indicated:

William Lawrence Saunders Gold Medal, 1959 to **John B. Knaebel.** AIME Annual Banquet, February 18.

Anthony F. Lucas Gold Medal, 1959 to **John T. Hayward,** AIME Annual Banquet, February 18.

Benjamin F. Fairless Award to **J. L. Mauthe.** AIME Annual Banquet, February 18.

Rossiter W. Raymond Award, 1959 to **John J. Gilman.** Metallurgical Society Dinner, February 17.

Mathewson Gold Medal to **John J. Gilman.** Metallurgical Society Dinner, February 17.

(Continued on page 821)

To the Members of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc.:

The regular Annual Business Meeting of the Institute will be held on Tuesday afternoon, the 17th day of February, 1959, following the All-Institute Session at the Annual Meeting of the Institute in San Francisco.

Fifth Volume of Nuclear Metallurgy Published

The Metallurgical Society of the AIME has published Volume V of *Nuclear Metallurgy.* It contains papers from a symposium given by the Institute of Metals Division at the Society's Fall Meeting in Cleveland.

The contents of the volume include, *Fabrication of Ceramic Fuel Elements by Swaging,* by D. R. Stenquist and R. J. Ancetti; *Fabrication of Aluminum Plate-Type Elements Containing Uranium Dioxide As the Fuel,* by S. I. Megeff and J. L. Zambrow; *Fabrication and Properties of Uranium-Zirconium Hydride Fuel Elements for Triga Reactors,* by W. P. Wallace, M. T. Simnad, and B. Turovlin; and *Fabrication of Iron-Aluminum-Chromium Alloy Fuel Plates,* by B. King, J. Neri, and F. G. Tate. Copies of the entire volume may be ordered from *AIME, 29 West 39 St., N. Y.* Price $6.00 for non-members; $4.00 for members.

Bylaws Available

Amended bylaws of The Metallurgical Society in multilithed form are available to any member who requests them. As an economy measure, they are not being reproduced in JOURNAL OF METALS, freeing the space for items of greater interest.

The bylaws of the three divisions, Extractive Metallurgy Division, Iron and Steel Division, and Institute of Metals Division, have all been revised since reorganization of AIME, in order that they conform with the bylaws of The Metallurgical Society. Copies of division bylaws are available upon request.

Bylaws of the Council of Education, an all-Institute organization, are also available in multilithed form.

Requests should be addressed to:

Secretary
The Metallurgical Society of AIME
29 West 39th Street
New York 18, N. Y.

A. FLETCHER

Andrew Fletcher Elected New UET President

Andrew Fletcher, president of the St. Joseph Lead Co., has assumed the additional responsibilities of president of United Engineering Trustees Inc.

Founded in 1904 to advance the engineering arts and sciences, the United Engineering Trustees Inc. represents the five professional societies of the major engineering branches with three board members from each. The Corporation directs the research programs of the Engineering Foundation as well as many other joint activities.

Mr. Fletcher is a Past President of AIME and was awarded the *Charles F. Rand Gold Medal* in 1957 for "distinguished administration in nonferrous mining and metallurgical enterprises." He is also chairman of the Industrial Hygiene Foundation of America, vice president and treasurer of the American Mining Congress, and past president of Lead Industries Assn.

Mr. Fletcher's acceptance of the presidency of United Engineering Trustees Inc. is in accord with his belief in public service, as is evidenced by his activities in his home community of Mendham, N. J., where he is a member of the Council, trustee of the Library, and trustee of the Presbyterian Church. He attended the Hill School in Pottstown, Pa., and graduated from the Sheffield Scientific School, Yale University, in 1916. Since that time he has received three honorary degrees in engineering and law.

After a year in the Harlan and Hollingsworth shipyard at Wilmington, Del., as a mechanic, Mr. Fletcher went to Baltimore as a foreman for the Baltimore Dry Dock Co. In 1918 he became secretary of the W. & A. Fletcher Co., Hoboken, N. J., and in 1924 was in direct charge of the business until the shipyard was sold to the United Dry Docks Inc. In 1929 he gave up his connection with the shipbuilding industry to become vice president and treasurer of St. Joseph Lead Co. He became executive vice president in 1946 and president in 1947.

United Engineering Trustees Inc. has purchased the block front between 47th and 48th Sts. on the United Nations Plaza for the construction of a 20-story Engineering Center, the cost of which is roughly estimated at $10,000,000. Their present home on West 30th St. will be sold. The Engineering Societies Library will move into the new Center where it will be able to expand the services which has already made it one of the finest public engineering libraries in the country.

In order to bring the benefits of centralized activities in the new Engineering Center to as widespread a group of engineers as possible, the five societies have extended invitations to other engineering societies to unite with them in using the new facilities as their headquarters. Thoroughly modern in every respect, the new Center will include, in addition to the headquarters office space for each group, such facilities as a cafeteria, dining rooms, meeting rooms, and a large memorial hall, suitable for group meetings or for major exhibitions of technical progress.

Mechanical Working Committee Symposium

The First Conference: Mechanical Working Committee Symposium will be held January 21, at the Del Prado Hotel, Chicago. This Symposium will be co-sponsored by the AIME Chicago Section, and the Iron and Steel Division of The Metallurgical Society of AIME.

Program

TUESDAY, JAN. 20, 1959

6:00 pm to 9:00 pm Registration
Main Ballroom Lobby

WEDNESDAY, JAN. 21, 1959

8:00 am Registration
Main Ballroom Lobby

9:15 am to 12 noon Main Ballroom
Symposium on Factors Affecting Shape and Surface Texture of Hot and Cold Rolled Products.

Chairmen:

R. Schuler, Manager, North Mills, Inland Steel Co., and Howard Kaeff, General Superintendent, Flat Rolled div., Youngstown Sheet & Tube Co., Chicago.

Factors Affecting Strip Profile in a Hot Strip Mill, J. G. Sibakin, Division Metallurgist, Development and Special Duties, J. R. S. Ride, Development Metallurgist, and W.

(Continued on page 821)

1959 AIME Publication Prices Are Determined

The following price information has been announced for AIME publications effective Feb. 1, 1959:

If payment for *AIME Transactions* volumes is made with dues, the cost per subscription is: *Mining*, $3.50; *Metals*, $5.00; and *Petroleum*, $3.50. If payment is made separately, the cost is: *Mining*, $4.90; *Metals*, $5.00; and *Petroleum*, $4.90.

If another journal (published by a different Society) is desired, in addition to the subscription received upon payment of annual dues (to the AIME Society of your choice), the additional monthly journal will cost $4.00.

A second subscription to any journal to which you are now subscribing costs $8.00.

Petroleum Statistics: Volume 12, published in December 1958, costs $7.50 if paid with dues, $10.50 if ordered later.

Bimonthly *Transactions of The Metallurgical Society of AIME* member subscription price is $5.00.

Dr. J. H. Hollomon Recipient of Rosenhain Medal

Dr. John H. Hollomon was presented the 1958 *Rosenhain Medal* on Tuesday evening, October 28th.

Awarded annually by the Institute of Metals, of London, England, the medal is bestowed on individuals who have made outstanding contributions in the field of metallurgy.

The official presentation was made during the Fellowship Dinner held by the Institute of Metals Division of The Metallurgical Society of AIME. Dr. R. A. Wilkins, vice president of Revere Copper and Brass, Inc., presented the award.

Dr. Hollomon is manager of the Metallurgy and Ceramics Research Department, at the General Electric Laboratory.

J. H. HOLLOMON

AROUND THE SECTIONS

Buffalo NOHC Section Holds Annual Meeting

The Ninth Annual Meeting of the Buffalo Section of the National Open Hearth Steel Committee was held in the Hotel Statler Hilton, on Tuesday, Nov. 11, 1958.

The program included the presentation of the *McKune Award* papers from the Buffalo Section, and a trip to the Ford Motor Co. stamping plant at Woodlawn.

Mr. Floyd Eckhart, assistant general manager, Lackawana Steel Plant of Bethlehem Steel, presented in an after dinner talk, his *Personal Experience in the U.S.S.R.* based on a recent trip to Russia.

Tennessee Coal and Iron Host to Southwestern Section, NOHC

The **Southwestern Section** of the National Open Hearth Steel Committee, commonly known as the *Globe Trotters*, journeyed to Birmingham, Ala., for the first time. The Tennessee Coal and Iron Division of United States Steel Corp. served as the host for the 21st Anniversary Meeting, which was held on October 9th and 10th, at the Dinkler-Tutwiler Hotel in Birmingham. A total registration of 179 was recorded.

The program began on October 9 with a plant trip to the Fairfield works of the Tennessee Coal and Iron Division. Visits were made to the open hearth furnaces, blooming mills, strip mills, and tin mills. The Fellowship Dinner, which followed a social hour, was through the courtesy of suppliers. Serving as toastmaster was B. R. Queneau, Tennessee Coal and Iron Division, United States Steel Corp., Fairfield, Ala. Speaker of the evening was Lewis L. Gober, chief of the engineering branch, Industrial Division, Army Ballistics Missile Agency, Redstone Arsenal, Ala. His topic was *The Ballistic Missile Weapon System—Testimony of Today's Technology.*

Technical sessions got under way on October 10th, with Dr. B. R. Queneau, program chairman, serving as the session chairman. He was assisted by R. W. Sandelin, co-chairman and chief metallurgist and melting susuperintendent of Connors Steel Division of H. K. Porter Co., Inc., Birmingham. The first paper, *Deoxidation and Pouring Practices for Mechanically Capped and Rimmed Steels*, was co-authored by Marcel Tarris and L. Pucker, Granite City Steel Co. Messrs. Tarris and Pucker described the use of bottle-top ingot molds at their plant. *Open Hearth Applications of Statistical Methods*, by A. L. Raich, Colorado Fuel and Iron Corp., described the application of statistics and quality control techniques to steel production.

A paper on *Vacuum Degassing of Steel* was given by John Hornak of United States Steel Corp. Having established the fact that hydrogen contributed to the thermal flaking of rotor forgings, Mr. Hornak pointed out the need for controlling the hydrogen content of steel. Vacuum degassing equipment was designed to operate at 0.1 pct of normal equilibrium pressures. This equipment has no refractories, no water cooling, and produces steel of 1.5 ppm or less of hydrogen. Under the heading *Progress Report on*

(Continued on page 821)

Shown chatting at the guest table during the September 27th, *Annual Columbia Falls Meeting* held jointly by the Montana Section and the Anaconda Aluminum Co.'s technical society were, left to right: the featured speaker, Mr. Lee Holscher, coordinator of production work for Kaiser Aluminum Co., Trentwood, Wash.; and Mr. E. O. Woster, general superintendent, Anaconda Aluminum Co., Great Falls, Mont., who gave the welcoming talk. Fifty-three members attended this special event which was held at the Anaconda Aluminum Co.'s Employees Club at Columbia Falls.

Energy and The Production of Metals was the topic of Dr. L. M. Pidgeon, guest speaker at the October 1st dinner-meeting of the **Niagara Frontier Section,** held at the Treadway Inn, Niagara Falls, N.Y. Dr. Pidgeon is Head of the Department of Metallurgical Engineering at the University of Toronto, Toronto, Canada. At the business meeting, the Nominating Committee for Officers and Directors was chosen. They are: Chairman, D. C. Hilty, Metals Research Laboratories; G. B. Michie, Electro Refractories and Abrasives Corp.; D. L. Clark, Simmonds Saw and Steel Co.; E. A. Gietzen, Bethlehem Steel Corp.; G. L. Cox, International Nickel Co.; and M. S. Burton, Cornell University.

Sixty-five members and guests of **Lima-Peru Section** heard Dr. Juan E. Elguera, legal advisor to the Cerro de Pasco Corp. in Lima, Peru speak on *The United Nations Nonferrous Metals Exploratory Conference Held In London.* Dr. Eleguera was the Peruvian government representative to the United Nations conference on nonferrous metals recently held in London, England.

The **Montana Section** met on October 22nd in the metallurgy building of the Montana School of Mines, as guests of the Butte Mineral and Gem Club, Butte, Mont. Mr. Murl H. Gidel, retired assistant chief geologist, The Anaconda Co., was the guest speaker. He supplemented his talk on *Volcanology* with a new sound color film entitled, *The Eruption of Kilavea Volcano.* On November 1st, the Section met for cocktails and dinner at the Marine Room of the Schell Town House, Great Falls, Mont. The featured speaker, Mr. Ed Woster, discussed *Aluminum Production.* Mr. Woster is general superintendent of The Anaconda Aluminum Co., Columbia Falls, Mont.

Program on Stress Corrosion Fracture Technical Conference

The Technical Conference on *Physical Metallurgy of Stress-Corrosion Fracture* will be held at Mellon Institute, Pittsburgh, on Thursday and Friday, April 2-3, 1959. The Conference will be sponsored by the Corrosion-Resistant Metals Committee of the Institute of Metals Division, The Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers, in cooperation with the Electrochemical Society, the National Association of Corrosion Engineers, and the American Society for Testing Materials. The Pittsburgh Section of AIME will serve as the host.

The program of the Conference is designed to provide a broad basis for presentation and discussion of recent fundamental advances in stress-corrosion cracking.

The meetings will be of the discussion type. The speakers will present summaries of their papers with emphasis on what they think is new and significant. Papers will be preprinted for circulation and study prior to the Conference. In this way a major portion of the program will be allotted to discussion and exchange of scientific information. The papers and discussion will be printed in Proceedings to be distributed to all registrants.

The complete program will cover two days of sessions as indicated below:

9:00 am

Session I—Introduction and Theoretical Aspects of Stress, Corrosion, and Fracture

Chairman

G. M. Pound, Dept. of Metallurgy, Carnegie Institute of Technology

Brief Remarks on Objectives of Conference: T. N. Rhodin, Dept. of Engineering Physics, Cornell University.

New Perspectives in the Stress Corrosion Problem: H. H. Uhlig, Dept. of Metallurgy, Massachusetts Institute of Technology.

Characteristics of Stress Corrosion Cracking: A. W. Dana, Engineering Research Laboratory, E. I. du Pont de Nemours and Co.

Relationships of Microstructure to Fracture: J. J. Gilman, Research Laboratory, General Electric Co.

Relationships Between Stress and Chemical Potentials: Ling Yang, C. T. Horne, and G. M. Pound, Dept. of Metallurgy, Carnegie Institute of Technology.

Effects of Solid Structure on Surface Behavior: D. Turnbull and G. Ehrlich, Research Laboratory, General Electric Co.

2:30 pm

Session II—Experimental Aspects of Stress, Corrosion, and Fracture

Chairman:

H. H. Uhlig, Dept. of Metallurgy, Massachusetts Institute of Technology.

Crack Propagation in Ductile Crystals and Its Bearing on Stress Corrosion: A. J. Forty, Dept. of Physics, Bristol University.

Role of the Corrosion Product: N. A. Nielsen, Engineering Research Laboratory, E. I. du Pont de Nemours and Co.

Effect of Stress and Environment on the Microtopology of the Corrosion Product: E. A. Gulbransen and Thomas Capon, Research Laboratory, Westinghouse Electric Corp.

9:00 am

Session III—Physical Metallurgical Aspects of Stress Corrosion

Chairman:

E. J. Kreh, Bettis Atomic Power Div., Westinghouse Electric Corp.

Effect of Composition on Stress Corrosion Cracking of Some Alloys Containing Nickel: H. R. Copson, Research Laboratory, International Nickel Co.

Propagation of Stress Corrosion Cracks: C. Edeleanu, Research Laboratory, Tube Investments Co., England.

Dependence of Stress Corrosion Cracking Susceptibility on Age-Hardening in a Copper-Nickel-Silicon Alloy: W. D. Robertson, I. G. Grenier, W. Davenport, and V. Nolle, Dept. of Metallurgy, Yale University.

Summary and Comments on Conference: L. R. Sharfstein, Bettis Atomic Power Div., Westinghouse Electric Corp.

Because of the emphasis on the discussion nature of the Conference, available facilities will limit participants to 400. Inquiries regarding pre-registration should be directed promptly to the Chairman of the Arrangements Committee:

Professor William R. Bitler

Department of Metallurgical Engineering

Carnegie Institute of Technology

Pittsburgh 13, Pennsylvania

★ AIME Names 1959 Class Legion of Honor List ★

Each year at the Annual Banquet in February, those members of the AIME who have continuously maintained their membership for 50 years are given special recognition. They are seated at the head table as guests of the Institute and are added to the membership of the Legion of Honor. Those who will achieve this status in 1959 are as follows:

Allen, Roy H.
Banning, Calif.
Bancroft, Howland
New York
Berg, H. A.
Birmingham
Burchard, E. F.
Washington, D. C.
Busey, A. P., Jr.
Burlingame, Calif.
Herz, Nathaniel
Lead, S. D.
Irwin, David D.
Winnetka, Ill.
Jackman, Herbert E.
Rochester, N. Y.
Jenks, Norman L.
Narino, Columbia
Lassiter, Robert G.
Ashe City, N. C.
McAuliffe, Eugene
Omaha, Neb.
McCart, Robert, Jr.
Forth Worth, Texas
Ruggles, Guy H.
Cananea, Mexico
Rutherford, William P.
Glasgow, Scotland
Sayre, Mortimer F.
Schenectady, N. Y.
Smith, H. DeWitt
New York
Soper, E. K.
Los Angeles
Wolf, Albert G.
Houston

AIME Awards

(Continued from page 817)

J. E. Johnson, Jr. Award, 1959 to **Clarence T. Marshall,** Metallurgical Society Dinner, February 17.

Robert Peele Memorial Award, 1959 to **F. R. Jones.** Mining and Exploration Division Luncheon February 18.

Extractive Metallurgy Division Award, 1959 to **W. A. Krivsky** and **R. Schumann, Jr.,** Extractive Metallurgy Division Luncheon, February 18.

Robert Lansing Hardy Gold Medal, 1959 to **Norbert F. Neumann.** This award will be presented at a meeting of the St. Louis Section.

Howe Memorial Lecturer, Clarence E. Sims. Certificate presented at the lecture, February 17.

Institute of Metals Division Lecturer, 1959 to **Frederick Seitz.** Certificate presented at the lecture, February 18.

Daniel C. Jackling Award and Lecture, 1959 to **Ralph S. Archibald.** Mining and Exploration Division Luncheon, February 18.

Cedric K. Ferguson Medal, 1958 to **Jim Douglas, Jr., Philip M. Blair,** and **R. J. Wagner.** This award was presented at the SPE fall meeting on October 7.

John Franklin Carll Award, 1958 to **Ernest O. Thompson.** This award was also presented at the SPE fall meeting on October 7.

Hal Williams Hardinge Award, posthumously awarded to **Oliver Bowles.** Presentation to be made to Mrs. Bowles in the spring of 1959.

JOINT AWARDS

John Fritz Medal, to **Mervin J. Kelly,** presented at AIME ceremonies.

Percy Nicholls Award, 1958, to **Willibald Trinks,** presented at the AIME-ASME Joint Solid Fuels Conference, October 9.

Alfred Nobel Joint Prize, 1958 to **G. Farmanfarma.** Presented at AIEE ceremonies.

Southwestern, NOHC

(Continued from page 819)

Basic Construction in the Open Hearth, two additional papers were presented. A. H. Sommer of Keystone Steel and Wire Co. reviewed past operating experience and progress in the use of basic brick in open hearth construction in the US and Canada, and summarized the work at his own company. R. N. Ames of United States Steel Corp. reported on an experiment at South works, in Chicago, in which a basic furnace in operation since 1947 had produced 7684 heats in February, 1958, as opposed to an average of 6923 heats per furnace with silica construction during the same time interval.

The afternoon chairmen were Loren Wright, superintendent of steel production, Republic Steel Corp., Gadsden, Ala., and Steven Penny, superintendent of open hearth, Fairfield works of the Tennessee Coal and Iron Division. In the opening paper, W. E. Crouch, Jr., vice president of Tennessee Coal and Iron Division, described the *Training of Salaried Employees* by his company. Mr. Crouch pointed out that although *equipment* has been constantly improved and *processes* advanced through changing techniques, *people* are unchanged. Hence, there is an essential need for orientation, indoctrination, and training of personnel. Every supervisor attends a 40-hr course on instructional techniques, human relations, basic economics, and good citizenship.

Two papers were presented on *Open Hearth Gunning Practices*. S. M. Purcell cited that the use of "guns" to repair open hearth furnaces at Lone Star Steel Co., produced these advantages: 1) greatly increased quality of repairs; 2) decreased delay time; 3) decreased quantity of materials used; 4) decreased work of furnace crew; and 5) tap holes kept to a desirable size. Experience at Gary works, United States Steel Corp., in using guns for lining bifurcated spouts, was described in a paper written by Orville Haniford, and in his absence due to illness, read by Samuel Muletick.

Richard Morgan described *Slag Handling* at Colorado Fuel and Iron Corp., Pueblo, Colo. Long delays in handling slag with outmoded equipment to a distant dump were ended by the use of diesel-powered trailer trucks which hauled the pots directly from the pouring pit to the slag dump. This cycle takes only 15 min instead of a time interval formerly measured in hours. Thus, a serious bottleneck was eliminated. A panel discussion, *Correct Baling of Scrapped Automobiles*, led by W. S. Storey of the Institute of Scrap Iron and Steel Inc., marked the first time that scrap dealers have appeared on a technical program before open hearth operators. Scrapping of automobiles was demonstrated by use of a model, and the research on scrap handling, initiated at Battelle Memorial Institute, was also described.

Responsible for arranging the 2-day meeting was George Grosvenor, chairman of the Southwestern Section, and open hearth superintendent, Colorado Fuel and Iron Corp., Pueblo, Colo.; L. D. Yager, co-chairman, and open hearth superintendent, Laclede Steel Co., Alton, Ill.; N. M. Hunthausen, secretary-treasurer, and assistant sales manager, Mexico Refractories Co., Mexico, Mo.; and Harry Hausner, Jr., assistant secretary-treasurer, and sales engineer, E. J. Lavino and Co., Chicago, Ill. The technical program was organized by B. R. Queneau, who was assisted by E. G. Balog, assistant chief quality control metallurgist-manufacturing of the Tennessee Coal and Iron Division.

Mechanical Working Committee Symposium

(Continued from page 818)

Sherwood, Development Metallurgist, The Steel Co. of Canada Ltd., Ontario.

Influence of Hot Strip Profile on Subsequent Operations, J. F. Griffin and G. R. Christoph, Metallurgical Operations, U.S. Steel Corp., Pittsburgh.

Panel Discussion, **Surface Texture, Flat Rolled Products.** W. H. Rees, Assistant Manager, Wide Strip div., Great Lakes Steel Corp., Ecorse, Mich.

W. R. Weir, Chief Metallurgist, Dominion Foundries and Steel Co., Ltd., Hamilton, Ont., Canada

F. F. Aloi, Metallurgical Engineer, Bethlehem Steel Co., Bethlehem, Pa.

J. A. Ward, Superintendent, Cold Reduction and Tin Mills, The Steel Co. of Canada, Ltd., Hamilton, Ont., Canada

S. Daily, General Foreman, Finishing, No. 3 Cold Strip Mill, Inland Steel Co., Indiana Harbor, Ind.

E. Spangler, Superintendent, Gary Sheet and Tin Div., U.S. Steel Corp., Gary, Ind.

12:00 noon — Lunch (included in cost of registration)

Speaker: George F. Sullivan, Editor, THE IRON AGE, Philadelphia, Pa.

Subject: *An Insider's Look at the Russian Steel Industry*

2:00 pm to 5:00 pm — Main Ballroom

Symposium on Continuous Heat Treatment of Flat Rolled Products

Chairmen:

A. Miller, Manager Tin Mills, Weirton Steel Corp., Weirton, W. Va. and M. Edge, Superintendent, Tin Mills, Tennessee Coal and Iron div., U. S. Steel Corp., Birmingham, Ala.

Continuous Normalizing of Flat Rolled Products, D. C. Osborne, Assistant General Superintendent, Armco Steel Corp., Middletown, Ohio.

Continuous Strip Annealing, D. J. Blickwede, Research Metallurgist, Bethlehem Steel Co., Bethlehem, Pa.

(Continued on page 823)

Fall Meeting Program

(Continued from page 817)

Tuesday Morning, February 17

Institute of Metals

1. Two sessions based on research abstracts.

Extractive Metallurgy

1. Electrolytic Extractive Processes.
2. Symposium on Gases in Light Metals.

Iron and Steel

1. Basic Oxygen Steel.
2. Howe Lecture.

Tuesday Afternoon, February 17

All-Institute Session (Palace Hotel).

Wednesday Morning, February 18

Institute of Metals

1. Two sessions based on research abstracts.
2. IMD Annual Lecture.

Extractive Metallurgy

1. Zinc
2. Occurrence, Beneficiation, and Separation of Rare Earths.

Joint Extractive Metallurgy—Iron and Steel

1. Kinetics of Liquid Metal Reactions.

Wednesday Afternoon, February 18

Institute of Metals

1. Scale Effects on Mechanical Properties.
2. Session based on research abstracts.

Extractive Metallurgy

1. Rare Earth Metals.

Joint Extractive Metallurgy—Minerals Beneficiation

1. Cobalt—Nickel.

Joint Extractive Metallurgy—Iron and Steel

1. Application of Phase Equilibria to Metallurgical Systems.

Iron and Steel

1. Steelmaking Technology.

Thursday Morning, February 19

Institute of Metals

1. Alloy Strengthening at Elevated Temperatures.
2. Session based on research abstracts.

Extractive Metallurgy

1. Refractories.
2. Chlorination Processes I.
3. First EMD Lecture.

Iron and Steel

1. Basic Science of Steelmaking.

Thursday Afternoon, February 19

Institute of Metals

1. Alloy Strengthening at Elevated Temperatures.
2. Session based on research abstracts.

Extractive Metallurgy

1. Chlorination Processes II.

Joint Extractive Metallurgy—Minerals Beneficiation

1. Uranium

Joint Extractive Metallurgy—Iron and Steel

1. Pyrometallurgical Processes.

Iron and Steel

1. Gas—Metal Research.

1959 AIME Officers

At the Novemebr AIME Board of Directors Meeting, the officers of AIME for 1959, and five other Directors named to take office for three-year terms in that year, were officially declared elected. They are as follows: *President-Elect*, Joseph L. Gillson; *Vice Presidents and Directors*, Elmer A. Jones, Thomas C. Frick, Walter R. Hibbard, Jr., and J. C. Kinnear, Jr.; *Directors*, Arthur B. Cummins, J. W. Woomer, John S. Bell, John Chipman, and Carlton C. Long.

Change of Address and Personals Form

To be sure that you receive your publications and correspondence promptly, please fill in the form below and send it to **The Metallurgical Society of AIME**, 29 W. 39th St., New York 18, N.Y.:

Name _____

Old Address _____

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New Address _____

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Personals: Please list below your former company and title and your new title and company (or new work) for use in JOURNAL OF METALS. (Copy deadline for personals items is six weeks before date of issue.)

Former Company _____

Former Title _____ Length of Time There _____

New Company _____

New Title _____ Date of Change _____

Any recent activity that would be of interest to members:

_____

_____

_____

_____

PROPOSAL FOR AIME MEMBERSHIP

I consider the following person to be qualified for membership and request that a membership kit be mailed to him:

Name of Prospective Member:

_____

Address

_____

_____

_____

Name of AIME Member:

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JM

Symposium

(Continued from page 821)

Continuous Coil Annealing. Lee Wilson, Lee Wilson Engineering Co., Cleveland, Ohio.

Open Discussion on Strip Cleanliness after Annealing.

5:00 pm to 6:00 pm Social Hour
Park View Room

GENERAL INFORMATION

Registration: $12.50 (includes cost of lunch and copy of procedings).

Advance registration may be made by sending a check to *Phillip H. Smith, La Salle Steel Co., P. O. Box 6800A, Chicago 80, Ill.*

Del Prado Hotel—Located at Hyde Park Blvd. and 53rd St. All Illinois Central and "Big Four" trains stop at 63rd St., convenient to hotel.

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R. W. Shearman	Sec. Treasurer

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Local Committee on Arrangements

C. F. Schrader	Chairman
T. D. Hess	Co-chairman

P. Smith, Paul White, Earl Mahaney

OBITUARIES

Clarence L. Corban (Member 1942) passed away on May 13, 1958. He was manager of coke production of Inland Steel Co. in Hammond, Indiana. Active in AIME, Mr. Corban was a member and one-time chairman of the JOURNAL OF METALS Award Committee and vice chairman of the Blast Furnace, Coke Oven, and Raw Materials Committee. He had been a past president of the Western States Blast Furnace and Coke Association, and a member of the Eastern States Blast Furnace and Coke Association; member of the Iron and Steel Institute; chairman of the Technical Committee on Coke Oven Practice, and a member of American Iron and Steel Institute. At the time of his death, Mr. Corban resided in Hammond, Indiana.

Victor A. Crosby (Member 1939) died on Oct. 2, 1958 in Detroit. A member of the Climax Molybdenum Co., since 1934, he was manager of the automotive development center. He had been a member of the AIME section in Detroit. In 1951, he was the recipient of the *John A. Penton Gold Medal* of the American Foundrymen's Society, and in 1952 he was elected a vice president of the Society of Automotive Engineers, Inc. At the time of his death, Mr. Crosby resided in Detroit.

Fritz N. Meyer (Member 1920) passed away on July 24, 1958. Mr. Meyer graduated from Worcester Polytechnic Institute, and during his career was associated with the American Brass Co., Waterbury, Conn.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Sept. 1, 1958 was 30,496; in addition 3,125 Student members were enrolled.

ADMISSIONS COMMITTEE

J. H. Scaff, Chairman; Alfred Bornemann; F. B. Foley; T. D. Jones; L. L. Seigle; J. M. Warde, H. K. Work.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

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Erik Anders, Domnarvet, Swed.
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Elliott DeLauro, Gary, Ind.
Daniel J. Herts, New York, N. Y.
Robert J. O'Hara, New York, N. Y.

1959 AIME Dues Bills Mailed

Notice is hereby given that dues for the year 1959 are payable Jan. 1, 1959, as follows: Members and Associate Members, $20; Junior Members for the first six years of Junior Membership, $12, and thereafter, $17; Student Members (including an annual subscription to a monthly journal), $4.50.

Dues bills were mailed at the end of November. Prompt payment will assure uninterrupted receipt of the publications desired in 1959. If, for any reason, a bill is not received within a reasonable time, headquarters should be notified.

Junior Members

Lucian G. Bonar, Berkeley, Calif.
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Associate to Member

Louis S. Castleman, Bayside, N. Y.
James L. Scott, Oak Ridge, Tenn.

Student to Junior

John P. Hirth, Pittsburgh, Pa.

NECROLOGY

Date Elected	Name	Date of Death
1942	Clarence L. Corban	May 13, 1958
1939	Victor A. Crosby	Oct. 2, 1958
1920	Fritz N. Meyer	July 24, 1958

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COMING EVENTS

Dec. 3-5, AIME 16th Electric Furnace Conference, Statler Hotel, Detroit.

Dec. 8-10, AIME Detroit Section, American Nuclear Society, Winter Meeting, Detroit.

Dec. 11, AIME Utah Section, Panel discussion on the Place of Research in the Minerals Industries, Salt Lake City.

Jan. 15, AIME Utah Section, speaker: Harold Wright, *Rubber and Plastic as Cost Savers in Metallurgical Installations.* Mr. Wright is executive vice-president of Galigher Co.

Feb. 15-19, 1959, AIME Annual Meeting, St. Francis Hotel, Sheraton-Palace Hotel, and Sir Francis Drake Hotel, San Francisco.

Apr. 2-3, 1959, AIME Technical Conference on Stress Corrosion, Mellon Institute, Pittsburgh.

Apr. 6-8, 1959, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis.

Apr. 5-10, 1959, Fifth Nuclear Congress, Cleveland Auditorium, Cleveland.

Apr. 22-26, 1959 AIME Florida Section, Annual spring meeting of the Metal Treating Institute, Hollywood Beach Hotel, Hollywood, Florida.

Apr. 27-30, 1959, AIME International Symposium on the Physical Chemistry of Process Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

Dec 2-4, 1959 AIME Cleveland Section, 17th Electric Furnace Steel Conference, Hotel, Cleveland.

Feb. 14-18, 1960, AIME New York Section, Annual Meeting, Hotel Statler, New York.

Apr. 4-6, 1960 AIME Chicago Section, Blast Furnace & Open Hearth Conference, Palmer House, Chicago.

Sept. 27-30, 1960, AIME Cleveland Section, the Iron and Steel Exposition of the Association of Iron and Steel Engineers, Cleveland Public Auditorium, Cleveland.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPA.

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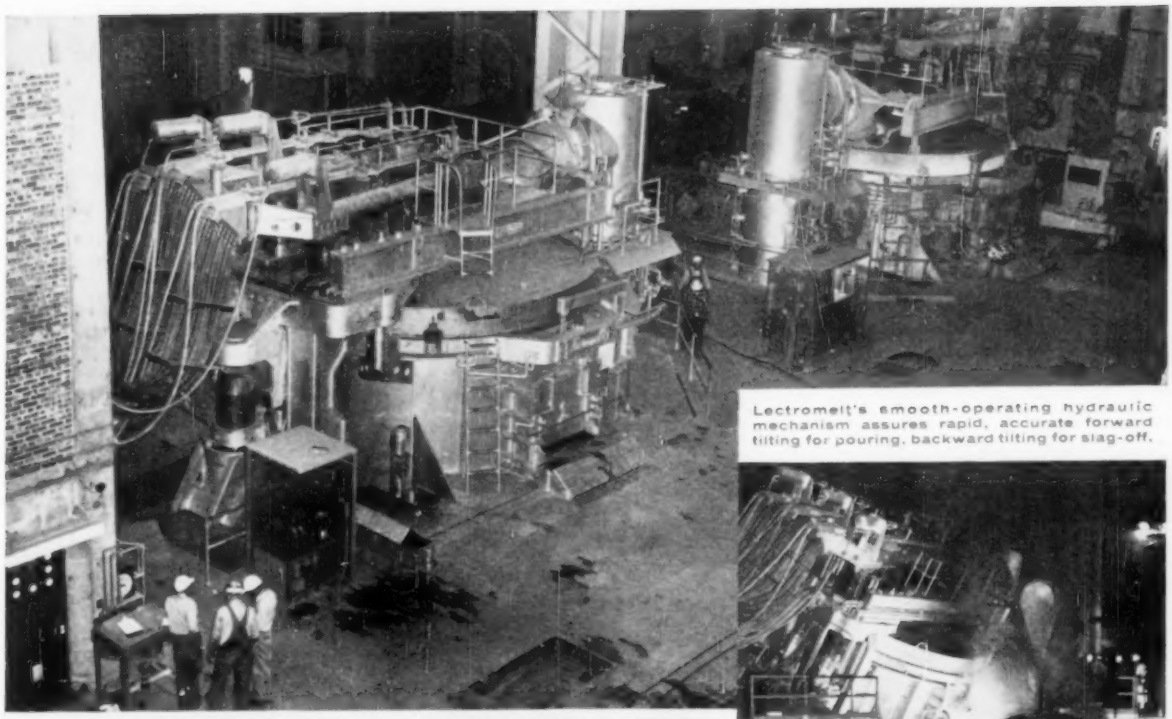

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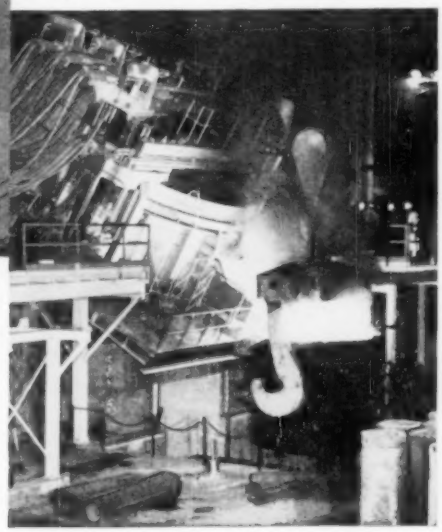

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